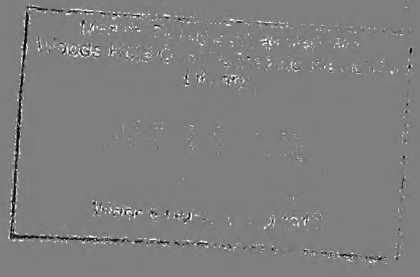
# TRANSACTIONS

OF

# THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

1910



VOL. XVIII 1910

# TRANSACTIONS

OF

# THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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EDITED BY THE SECRETARY

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Thomas, Joseph D.
Thomas, S. B.
Thompson, Robert M.
Thorp, Harry W.
Thresher, Alfred A.
Toch, Henry M.
Todt, Edward G.
Tomikawa, Naoji.

Vanderbilt, Aaron.
Van Duzer, Louis S.
Vassileff, Dimitry.
Veit, Richard C.
Vreeland, Charles E.

Wales, Charles M.
Weinz, Charles J.
Welles, Roger, Jr.
Whitaker, F. B.
White, George A.
Whiton, Chauncey G.
Wierdsma, John R.
Williams, Ralph D.
Williams, William E.
Wood, David.
Wood, Henry A. W.
Wood, Howard.
Wright, William L.

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## JUNIORS.

Anderson, Robert E.

Bagger, Frank E.
Bailey, Daniel.
Bailey, Harris R.
Bailey, Robert W.
Bergstrom, Carl A.
Bretteville, Alex. de.
Briner, Emel A.
Burkhard, John C.
Callahan, Constantine D.
Caswell, W. B.
Chapman, Lawrence B.
Colby, Haldwell S.
Cook, Fayette A.

Crane, Frank H.
Curtis, Arthur V.
Cutler, Edward O.

Damon, Edward O., Jr.
Dougherty, Hugh.

Endgerdt, John A.
Erdman, George K.

Fermann, Wilhelm E.
Fils, Ernest.
French, Francis J.
Friebele, John F.

Hall, Francis G., Jr.
Hammond, Jay D.
Hermanrud, Torbjorn.
Herrick, Dayton E.
Hubbell, Charles W.
Hunnewell, Fred. A.
Hunt, Herman R.
Hussey, James W.
Jansson, A. H.
Jennings, Alfred C.
Johnson, Eads.

Leitch, Albert C.

Martin, Gilbert D.
Merrill, Ambrose M.
Mills, Roy P.
Mitchell, Leland R.
Musham, Harry A.

Newell, William S.
Norton, William J.

O'Donnell, Charles F.
Osborn, Edward B.

Rasmussen, Christian.
Rimmer, A. Cyril.

Schmidt, John D.
Shen, Heenan T.
Simpson, Dwight S.
Simpson, Robert C.
Sivard, Emar L. M.
Smith, Granville.
Smith, Joseph D. C.
Swasey, A. Loring.

Tappen, Alexander B.
Thompson, Lawrence M.
Thunberg, Ernst, Jr.
Towle, Howard C.

Uzelmeier, William.

Wallace, William L., Jr.
Watts, J. Murray.
White, Nathaniel A.
Whitehouse, Frederick C.
Wright, Henry C., Jr.

Young, William J. J.

# ARTICLES OF INCORPORATION.

## THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

STATE OF NEW YORK,
CITY AND COUNTY OF NEW YORK, } *ss:*

We, the subscribers, WM. H. WEBB, CHAS. H. CRAMP, GEORGE E. WEED, H. TAYLOR GAUSE, WILLIAM T. SAMPSON, HORACE SEE, FRANK L. FERNALD, FRANCIS T. BOWLES, WASHINGTON L. CAPPS, EDWIN D. MORGAN, GEORGE W. QUINTARD, HARRINGTON PUTNAM and JACOB W. MILLER, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller—are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

*First.* The name or title by which the Society shall be known in law is THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

*Second.* The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

*Third.* The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

*Fourth.* The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

*Fifth.* The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In WITNESS WHEREOF we have made, signed, and acknowledged this certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

CITY AND COUNTY OF NEW YORK, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

JAMES FORRESTER,
*Notary Public, Kings Co., Cert. N. Y. Co.*

CITY AND COUNTY OF NEW YORK, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

JAMES FORRESTER,
*Notary Public, Kings Co., Cert. N. Y. Co.*

CITY AND COUNTY OF NEW YORK, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

JAMES FORRESTER,
*Notary Public, Kings Co., Cert. N. Y. Co.*

(ENDORSED.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

EDWD. PATTERSON,
*Justice of the Supreme Court in the State of New York in and for the City and County of New York.*

# CONSTITUTION AND BY-LAWS OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

## ARTICLE I.

*Name and Object.*

1. The name of this Association shall be "THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS."

2. Its object shall be the promotion of the art of shipbuilding, commercial and naval.

3. In furtherance of this object, annual meetings shall be held for the reading and discussion of appropriate papers and interchange of professional ideas, thus making it possible to combine the results of experience and research on the part of shipbuilders, marine engineers, naval officers, yachtsmen, and those skilled in producing the material from which ships are built and equipped.

## ARTICLE II.

*Membership.*

1. The Society shall consist of Members, Associates, Juniors, Honorary Mem bers and Honorary Associates.

2. *Members.*—(1) The class of Members shall consist exclusively of Naval Architects, Marine and Mechanical Engineers, including Professors of Naval Architecture or Mechanical Engineering in colleges of established reputation.

(2) A candidate for this class must be not less than twenty-five years of age and comply with the following regulations:—He shall submit to the Council a statement showing that he has been engaged in the practise of his profession, in a responsible capacity, for at least three years, and setting forth his grounds upon which he bases his claim to membership. This statement shall be signed by three Members, who shall certify to their personal knowledge of the candidate and approval of his statement.

(3) In the case of persons not American citizens, the signatures of three Members shall be required in confirmation of their personal knowledge of the candidate's scientific attainments.

(4) If three-fourths of the Members of the Council present are in favor of the admission of the candidate, his name shall be submitted to the members of the Society at the next meeting, the voting to be by ballot, should a ballot be demanded.

3. *Associates.*—(1) The class of Associates shall consist of all persons who, by profession, occupation, or scientific attainments, are qualified to discuss the qualities of a ship.

(2) Candidates for this class shall submit to the Council a written statement of their qualifications for membership. If considered by three-fourths of the Council present duly qualified for Associate membership, their names shall be submitted to the Society at its next meeting, to be voted upon by the Members and Associates, voting to be by ballot, should a ballot be demanded.

4. The proportion of votes for deciding the election of Members and Associates shall be at least four-fifths of the number recorded.

5. *Juniors.*—(1) The class of Juniors shall consist of graduates of technical schools of established reputation, or persons who have not less than two years' practical experience in marine engine works or shipyards.

(2) Candidates must be at least eighteen years of age and certify their intention to continue in the profession and become naval architects or marine engineers.

(3) Juniors shall be eligible for transfer to the class of Members after fulfilling the necessary conditions; when they are twenty-six years of age they shall be offered the option of being transferred to active or associate membership, if they duly qualify; but if they do not accept such offer, or do not qualify, they shall be dropped from the rolls of the Society.

(4) The admission of Juniors shall be by a favorable vote of three-fourths of the members of the Council present.

(5) Juniors shall have no voice in the government of the Society or admission of members.

6. *Honorary Members and Honorary Associates.*—The Council may elect Honorary Members and Honorary Associates, the total number not to exceed twenty-five. They shall be persons of acknowledged eminence in their profession upon whom the Council may see fit to confer an honorary distinction.

## Article III.

### *Dues.*

1. The entrance fees, payable on admission to the Society, shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no fees.

2. The annual dues shall be as follows:—

Members and Associates, ten dollars; Juniors, five dollars; Honorary Members and Honorary Associates, no dues.

3. A member transferred from one grade to another shall pay the difference between the entrance fees of the two grades, and his annual dues shall be those of the grade to which transferred.

4. The annual contributions shall be payable in advance on the first day of January. The Secretary shall notify each member of the amount due for the ensuing year at the time of giving notice for the annual meeting. On election, each member shall pay his entrance fee and annual dues for the current year and be entitled to receive the proceedings of the annual meeting of the year during which he is elected.

5. Members and Associates can compound for all future dues and become Life Members and Life Associates, by making a single payment of two hundred dollars and signing an agreement to conform to any future amendments to the Constitution and By-Laws.

6. Members are entitled to no return of fees on severing their connection with the Society.

7. Any member whose dues are more than three months in arrears shall be notified by the Secretary. Should his dues become six months in arrears he shall be again notified by the Secretary and his rights as a member suspended. Should his dues become one year in arrears, the delinquent member shall forfeit his membership in the Society unless the Council may deem it expedient to extend the time of payment.

8. The Council may, in its discretion, temporarily suspend the annual payment of dues by any member whose circumstances have become such as to make such payment impossible, and may, under similar circumstances, remit the whole or a part of dues in arrears.

9. No name shall be entered on the rolls as Member, Associate or Junior, nor shall the privilege of membership be enjoyed until all dues shall have been paid; if the payment be delayed for more than six months from the date of election the same shall be void unless the Council otherwise direct.

10. (1) Should the expulsion of any member be judged expedient by five or more members, they must draw up and sign a proposal requesting such expulsion, delivering the same to the Secretary, to be laid before the Council.

(2) If the Council do not find reason to concur in the proposal, no entry thereof shall appear in the minutes, nor shall any public discussion thereon be permitted.

(3) If, however, the Council find the charges contained in the proposal for expulsion substantiated, the accused member shall be notified and given an opportunity to resign. If he avails himself of this privilege, no entry shall be made on the minutes nor public discussion of the case permitted; but if he declines to resign and offers no satisfactory explanation of the charge, the whole case shall be submitted to a special meeting of the Society.

(4) If two-thirds of the members at this special meeting (provided there be not less than twenty present) vote for expulsion, the chairman of the meeting shall cause the accused to be expelled from the Society, and direct the Secretary to notify the accused of this action.

## ARTICLE IV.

### *Officers.*

1. The officers of the Society shall consist of a President, Past Presidents, twelve Vice-Presidents, twenty-four Members of Council, and a Secretary and Treasurer.

2. Both Members and Associates are eligible for the offices of President, Vice-President, and Members of Council, but three-fourths of the Council shall be Members.

3. Prior to the date of the annual meeting of the Society of the year with which the term of the President expires, the Council shall nominate a candidate for the office of President, whose name shall be presented to the Society for election at the annual meeting. Any other candidate whose nomination, signed by at least sixty Members and Associates, shall have been submitted to the Secretary prior to the annual meeting shall also be presented. The candidate receiving the highest number of votes shall be the President for the ensuing three years. The first President under this rule shall be elected at the annual meeting in 1906 and his term of office shall begin January first, 1907. The President shall not be eligible for election as his own successor.

4. The term of office of the Vice-Presidents shall be six years. Prior to the annual meeting in 1906 the Executive Committee shall by lot divide the present list of Vice-Presidents into six classes, so that the term of two of their number shall expire at the end of 1906, and two others at the end of 1907, and so on to the year 1911. The Vice-Presidents to fill the vacancies occurring each year in any class shall be elected by the Council from their own membership. Retiring Vice-Presidents shall be eligible for re-election.

5. The term of office of the Members of Council shall be three years. Prior to the annual meeting in 1906, the Executive Committee shall by lot divide the present list of Members of Council into three classes, each class consisting, as near as may be, of six Members and two Associates. The terms of office of the three classes shall expire at the end of the years 1906, 1907, and 1908 respectively. Retiring Members and Associates shall be eligible for re-election. Prior to September first of each year the Executive Committee shall prepare voting lists to fill the places of retiring Members and Associates, Members of the Council. The list shall contain the names of at least twelve Members and at least four Associates as candidates for the vacancies. The lists shall contain the names of all retiring Members and Associates who shall not have declined re-election and of all candidates who shall have been nominated in writing by not less than twenty Members in the case of Members, and not less than twenty Members and Associates in the case of Associates. No nominations received by the Secretary after August fifteenth shall be considered. Should such nominations not be sufficient in number to fill up lists of at least twelve Members and four Associates as candidates, the Executive Committee shall add sufficient names to fill out these numbers. The voting lists shall be mailed as soon as practicable after September first of each year to Members and Associates. Each Member may vote for not more than six Members and two Associates for the Council, and each Associate may vote for not more than two Associates. The ballots shall be returned by mail to the Secretary and canvassed at the annual meeting. The six Members receiving the highest votes shall be declared elected Members of Council, and the two Associates receiving

the highest votes shall be declared elected Associate Members of Council, for the term of three years.

6. A vacancy in the office of President shall be filled by ballot by the Council from the list of Vice-Presidents until the end of the year in which it occurs. At the annual meeting of that year a new President shall be elected for three years in the manner prescribed in paragraph 3. A vacancy in the office of Member of Council shall be filled by the Council for the unexpired portion of the term of the Member or Associate causing the vacancy.

7. The Presidents, Past Presidents and Vice-Presidents shall be *ex-officio* Members of Council.

8. The Council may hold meetings, subject to the call of the President, as often as the interests of the Society may demand.

9. At all meetings of Council, five members shall constitute a quorum.

10. The Secretary and Treasurer shall be elected annually by the Council, but may be removed at any time by a majority vote of the Council after due notice has been given.

11. The Secretary must be a Member of the Society.

## Article V.

### *Management.*

1. The President shall have general supervision over affairs of the Society, appoint special committees, and preside at the annual general meetings. He shall be *ex-officio* member of all committees.

(2) In the absence of the President, the Vice-Presidents, in the order of seniority, shall preside and perform all the duties of the President.

2. The direct management of the Society shall be vested in an Executive Committee composed of five Members of Council elected annually by the Council, the President and Secretary of the Society being *ex-officio* members of the Committee. At least three of the five elective members of the Committee shall be Members of the Society.

3. The Executive Committee shall manage the affairs of the Society in conformity with the laws under which it is incorporated, and the provisions of the Constitution. It shall direct the investment and care of the funds of the Society; make appropriations for specific purposes; arrange for the reading and publication of professional papers under such regulations as the Council may, from time to time, prescribe; take measures to advance the interests of the Society, and generally direct its affairs.

4. The Executive Committee shall make an annual report to the Society, transmitting the report of the Secretary and Treasurer and of any special committee which may have been ordered.

5. The Secretary shall be the executive officer of the Society under the immediate direction of the President and Executive Committee.

(2) He shall prepare the business for the annual meetings and record the proceedings thereof.

(3) He shall be reponsible for all expenditures and certify the accuracy of all bills or vouchers upon which money has been paid, and he shall conduct the correspondence of the Society and keep full records of the same.

6. The Treasurer shall see that all money due the Society is collected and carefully invested in such manner as the Executive Committee may direct. If considered advisable by the Council, the duties of Treasurer may be performed by the Secretary.

7. The accounts of the Secretary and Treasurer shall be audited annually by a special committee of three Members of the Council appointed by the President of the Society.

## Article VI.

### *Meetings.*

1. There shall be at least one annual general meeting of the Society for the reading and discussion of professional papers, election of officers for the ensuing year, and transaction of such other business as may be brought before it. The time and location of this meeting shall be determined by the Council at least three months prior to the date fixed.

2. Special meetings may be called by the Executive Committee at the request of twenty members, which request shall state the purpose of the meeting. The call for such meetings shall be issued ten days in advance, and shall state the purpose thereof. At these meetings, thirty members shall constitute a quorum.

3. The Society may adopt from time to time such rules as it may think proper for the order of business at its meetings.

4. Special meetings of the Executive Committee may be held at any time subject to the call of the Chairman; and four members shall constitute a quorum for the transaction of any business that may be properly brought before the Committee.

## Article VII.

### *Amendments.*

1. Proposed amendments to this Constitution must be reduced to writing and signed by not less than ten members. They shall be forwarded to the Secretary at least ten days before the annual general meeting, and shall be immediately forwarded to the Council for its consideration. If a majority of the Council approve the proposed amendment, it shall be presented to the Society at the next ensuing general meeting for discussion; if approved by two-thirds of the members present, voting by ballot, if a ballot be demanded, it shall be adopted.

# INTRODUCTORY PROCEEDINGS.

EIGHTEENTH GENERAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

THURSDAY MORNING, NOVEMBER 17, 1910.

The Eighteenth General Meeting of the Society of Naval Architects and Marine Engineers was held in the United Engineering Societies Building, New York City, Thursday and Friday, November 17 and 18, 1909.

The President, Stevenson Taylor, called the meeting to order at 10.30 o'clock A. M., Thursday, November 17.

THE PRESIDENT:—The gentlemen will please come to order. The first in the order of business will be the reading of the Report of the Secretary-Treasurer by Secretary Baxter.

## REPORT OF SECRETARY-TREASURER.

NOVEMBER 10, 1910.

*To the Council,*

*Society of Naval Architects and Marine Engineers.*

GENTLEMEN: I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1910.

The membership of the Society, November 1, 1910, was as follows:—

| Class of Members. | At last report Nov. 1, 1909. | Elected 1909–1910. | Promotions Associates to Members. | Promotions Juniors to Members. | Deaths. | Resignations. | Suspensions. | | | Membership Nov. 1, 1910. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | At Annual Meeting, 1909. | By Authority of Council Since Annual Meeting. | Total. | |
| Members | 470 | 39 | A11 | A8 | 6 | 8 | 1 | 24 | 25 | 489 |
| Associates | 236 | 8 | —11 | —8 | — | 11 | 4 | 16 | 20 | 202 |
| Juniors | 76 | 8 | — | — | — | 3 | 4 | 7 | 11 | 62 |
| Life Members | 6 | — | — | — | — | — | — | — | — | 6 |
| Life Associates | 4 | — | — | — | — | — | — | — | — | 4 |
| Honorary Members | 1 | — | — | — | — | — | — | — | — | 1 |
| Honorary Associates | 3 | — | — | — | — | — | — | — | — | 3 |
| Totals | 796 | 55 | — | — | 6 | 22 | 9 | 47 | 56 | 767 |

The following deliquencies exist in the payment of dues:—

| | No. | Amount. | Total. |
|---|---|---|---|
| For the year ended December 31, 1906:— | | | |
| Associates | 3 | $30 00 | $30 00 |
| For the year ended December 31, 1907:— | | | |
| Members | 3 | 30 00 | |
| Associates | 3 | 30 00 | |
| | | | 60 00 |
| For the year ended December 31, 1908:— | | | |
| Members | 10 | $100 00 | |
| Associates | 9 | 95 00 | |
| Juniors | 4 | 20 00 | |
| | | | 215 00 |
| For the year ended December 31, 1909:— | | | |
| Members | 31 | $310 00 | |
| Associates | 21 | 210 00 | |
| Juniors | 12 | 60 00 | |
| | | | 580 00 |
| For the year ending December 31, 1910:— | | | |
| Members | 83 | $827 00 | |
| Associates | 43 | 430 00 | |
| Juniors | 32 | 160 00 | |
| | | | 1,417 00 |
| Total outstanding dues at October 31, 1910 | | | $2,302 00 |

During the past year, by authority of the Council, delinquent dues were charged off against suspended members to the amount of $2,247.28. These particular members were given every possible opportunity to avail themselves of continued membership and the amounts were held in abeyance until a final communication to each delinquent by registered mail failed to give results either in remittances or explanations of circumstances. This reduction in the Society's income, together with the loss from resignations and deaths passed upon at the November, 1909, session has brought the available income down to a reasonable estimate of its present worth.

FINANCIAL

RECEIPTS.

*From November 1, 1909, to October 31, 1910, inclusive.*

| | | |
|---|---|---|
| Entrance fees of new members for the year ending December 31, 1910:— | | |
| Members and Associates (45) | $450 00 | |
| Juniors (8) | 40 00 | |
| | | $490 00 |
| Promotion of Juniors to Members (7) | | 43 00 |
| Dues for year ending December 31, 1910:— | | |
| Members and Associates | $5,347 00 | |
| Juniors | 180 00 | |
| | | 5,527 00 |
| Dues for year ended December 31, 1909:— | | |
| Members and Associates | $1,763 00 | |
| Juniors | 130 00 | |
| | | 1,893 00 |
| Dues for year ended December 31, 1908:— | | |
| Members and Associates | $149 00 | |
| Juniors | 10 00 | |
| | | 159 00 |
| Dues for year ended December 31, 1907:— | | |
| Members and Associates | $60 00 | |
| Juniors | 15 00 | |
| | | 75 00 |
| Dues for year ended December 31, 1906:— | | |
| Members and Associates | $80 00 | |
| Juniors | 5 00 | |
| | | 85 00 |
| Dues for year ending December 31, 1911, paid in advance | | 35 00 |
| Sales of publications:— | | |
| Special editions of papers | $87 40 | |
| Society transactions to members and dealers | 1,008 05 | |
| | | 1,095 45 |
| Exchange on checks—members' dues | | 14 99 |
| Banquet—annual meeting, 1909 | $595 00 | |
| Annual meeting, 1910 | 30 00 | |
| | | 625 00 |
| Interest:— | | |
| On municipal bonds, City of New York | 647 50 | |
| On bank balances—Franklin Trust Company | 5 69 | |
| | | 653 19 |
| Recovery of transportation and expense charges | | 20 04 |
| Total receipts | | $10,715 67 |
| Balance, cash in bank and on hand, November 1, 1909 | | 152 85 |
| | | $10,868 52 |

STATEMENT.

DISBURSEMENTS.

*From November 1, 1909, to October 31, 1910, inclusive.*

| | | |
|---|---|---|
| Publications:— | | |
| Printing Volume 17 | $5,853 43 | |
| Miscellaneous printing | 305 12 | |
| Forwarding volumes, papers and membership year books | 113 81 | |
| Storage of volumes | 91 20 | |
| | | $6,363 56 |
| Rent of Safe Deposit Box, Franklin Trust Co | | 5 00 |
| Expenses 17th annual banquet, November, 1909 | | 680 47 |
| Expenses 17th annual meeting, November, 1909, postage, programmes, etc | | 494 47 |
| Expenses 18th annual meeting, November, 1910, postage, programmes, etc | | 78 21 |
| Special secretary, services and expenses, new members | | 445 00 |
| Exchange on remittances, members' dues | | 7 39 |
| Salaries and clerical expenses | | 1,333 34 |
| Audit of books and accounts to November 1, 1909 | | 150 00 |
| Rent of Society rooms | | 750 00 |
| Office expenses, postage, stationery, etc | | 490 21 |
| Total disbursements | | $10,797 65 |
| Balance, cash, October 31, 1910:— | | |
| In Franklin Trust Company | $70 17 | |
| On hand | 70 | |
| | | 70 87 |
| | | $10,868 52 |

*Statement of Resources and Liabilities.*

RESOURCES.

| | |
|---|---|
| Membership dues due from members after deducting for deaths and resignations ($50.00) and for doubtful accounts ($250.00) | $2,002 00 |
| Due from dealers for volumes | 816 50 |
| Publications on hand, at cost | 7,762 60 |
| Municipal bonds | 12,560 00 |
| Office furniture and equipment | 1,372 83 |
| Cash on deposit, Franklin Trust Company | 70 17 |
| Cash on hand | 90 |
| Total resources | $24,584 80 |

LIABILITIES.

| | |
|---|---|
| Balance due printer for Volume No. 17 | $600 00 |
| Society's present worth | $23,984 80 |

The financial statements have been verified by the Universal Audit Company of New York.

The following deaths and resignations have occurred during the past year:—

*Deaths* (6).

Members (6)—
W. T. Powell.
S. W. Robinson.
C. R. Roelker.
Horace See.
N. P. Towne.
F. M. Wheeler.

*Resignations* (22).

Members (8)—
R. H. Allen.
W. C. Besselievre.
W. A. Fairburn.
J. F. Hanscom.
J. B. Hoover,
P. H. Middleton,
J. W. Sims.
W. M. Wallace.

Associates (11)—
C. H. Arnold.
R. G. Bickford,
J. L. Bliss.
H. F. Bryan.
A. T. Chester.
T. B. Dick.
I. C. Hanscom.
F. P. Larkin.
J. G. Lindsay.
B. F. O'Connor.
W. P. White.

Juniors (3)—
C. T. Berry.
W. T. Dimm,
J. F. Sullivan.

Respectfully submitted.

WILLIAM J. BAXTER,
*Secretary-Treasurer.*

During the reading of the report of the Secretary, before the reading of the deceased members, the President said: "Gentlemen, rise in memoriam."

All the members present rose while the names of deceased members were read.

THE PRESIDENT:—What is your pleasure, gentlemen, as the report of the Secretary-Treasurer? It is also the report of the Council.

It was moved, seconded and carried unanimously that the Report of the Secretary-Treasurer be received and placed on file.

THE PRESIDENT:—Next in order is the announcement of the election of the following officers, by the Council:

VICE-PRESIDENTS.

*For the term expiring December 31, 1916.*

George W. Quintard, Quintard Iron Works, Foot 12th Street, New York.
Walter M. McFarland, Babcock & Wilcox Co., 85 Liberty Street, New York.

The Society by its ballots elected as—

MEMBERS OF COUNCIL.

*For the term expiring December* 31, 1913.

W. L. Babcock, Naval Architect, 17 State Street, New York.

W. F. Durand, Professor, Mechanical Engineering, Stanford University, Cal.

N. G. Herreshoff, Vice-President and General Manager, Herreshoff Mfg. Co., Bristol, R. I.

H. I. Cone, Engineer-in-Chief, U. S. Navy, Navy Department, Washington, D. C.

J. H. Linnard, Naval Constructor, U. S. N., retired, University Club, Philadelphia.

W. A. Post, General Manager, Newport News Shipbuilding and Dry Dock Co., Newport News, Va.

ASSOCIATE MEMBERS OF COUNCIL.

*For Term Expiring December* 31, 1913.

W. H. Brownson, Rear Admiral, U. S. N., retired, 1751 N Street N. W., Washington, D. C.

J. R. Andrews, President, Hyde Windlass Co., Bath, Me.

The Council elected as—

MEMBER OF COUNCIL.

F. L. DuBosque, Assistant Engineer, Floating Equipment, Pennsylvania Railroad Co., Jersey City, N. J., *vice* Horace See, deceased.

THE PRESIDENT:—The Secretary will now read the list of candidates for membership.

THE SECRETARY:—This list is submitted by the Council for election as members of the various classes of this Society. The Council has passed upon and recommends two life members, thirty-one members, four associate members, four junior members, and twenty-one transfers from associate members to full members. The names of the members are as follows:

*Transfer from Member to Life Member* (2).

Stevenson Taylor, President of Society.

Mason S. Chace, Naval Architect, 31 Wales Street, Dorchester, Boston, Mass.

*For Members* (31).

Joseph S. Blackett, Surveyor Lloyd's Register, 17 Battery Place, 247 79th Street, Brooklyn, N. Y.

Clarence A. Carr, Captain, U. S. N., Inspector of Machinery, U. S. Navy, Babcock & Wilcox Co. Bayonne, N. J., P. O. Address, 120 Hicks Street, Brooklyn, N. Y.

Harry C. Crosby, Chief Hull Draughtsman, The Moran Bros. Co., Seattle, Wash.

A. M. Dollar, Superintendent Engineer, Dollar Steamship Co., 160 California Street, San Francisco, Cal.

William J. DuBois, General Manager, American Mail S. S. Co., 100 Broadway, New York.

Dr. Ing. F. Gebers, Chairman, Imperial Experimental Station, Berlin N. W. 25, Schlenseninsal, Germany.

Arthur W. Berresford, General Manager, Cutler Hammer Manufacturing Co., Milwaukee, Wis.

Hermann Hullmann, Chief Constructor, German Navy, Berlin W., Reichs-Marine-Stat.

Francis J. S. Nolan, 453 Winslow Street, Camden, N. J., Marine Engineer, New York Shipbuilding Co., Camden, N. J.

Albert Norris, Lieutenant, U. S. Navy, Naval Academy, Annapolis, Md.

Bernard A. Sinn, 74 Broadway, New York, N. Y.

Gustav Schmitt, Ship and Engine Surveyor, 25 Whitehall Street, New York, N. Y.

Dr. Rudolph Veith, Engineer-in-Chief, German Navy, Berlin W. 50, Spichern-strabe 23.

Harry W. Warley, Superintending Engineer, Foreign Shipping, Standard Oil Co., 26 Broadway, New York, N. Y.

George J. Robinson, Superintendent, J. N. Robins Co., Erie Basin Dry Docks, Brooklyn, N. Y.

Anthony J. McGarvey, Superintendent, J. N. Robins Co., Erie Basin Dry Docks, Brooklyn, N. Y.

Albert W. Murray, Surveyor, Lloyd's Register of Shipping, 17 Battery Place, New York, N. Y.

Edmund Mills, Marine Department, Babcock & Wilcox Co., 85 Liberty Street, New York, N. Y.

William G. Lumsden, Mechanical Engineer, Electric Boat Co., Quincy, Mass.

Charles H. Bartlett, Chief Engine Draughtsman, Electric Boat Co., Quincy, Mass.

Gregory C. Davison, Vice-President, Electric Boat Co., 11 Pine Street, New York, N. Y.

Charles H. Bedell, Electrical Engineer, Electric Boat Co., Quincy, Mass.

Frank T. Cable, Superintendent, Electric Boat Co., Quincy, Mass.

Harry C. Farrar, Surveyor, Lloyd's Register, 173 80th Street, Brooklyn, N. Y.

Henderson B. Gregory, Inspecting Draughtsman, Bureau of Steam Engineering, Navy Dept., Washington, D. C.

Thomas H. White, Ship and Engine Surveyor, 77 Broad Street, New York, N. Y.

George Kotter, Superintending Engineer, Hamburg-American Line, 639 Garden Street, Hoboken, N. J.

Frank H. Evers, Surveyor, American Bureau of Shipping, 725 Castro Street, San Francisco, Cal.

Henry Black, Consulting Engineer and Ship Surveyor, 15 Whitehall Street, New York, N. Y.

William S. Rogers, Chief Draughtsman, The New England Navigation Co., Newport, R. I.

Frank S. Martin, Engineer and Naval Architect, 52 Beaver Street, New York, N. Y.

*For Associates* (4).

Charles E. Montgomery, Assistant to Superintending Engineer, Panama Railroad Steamship Line, 24 State Street. New York.

Benjamin B. Pender, General Foreman, Balboa Shops and Shipways, Balboa, Panama.

William E. Williams, The Williams & Wells Co., 250 Fulton Street, New York, N. Y.

Benoist d'Azy, Lieutenant Commander, French Navy, Naval Attache, French Embassy, Washington, D. C.

*From Associate to Members* (21).

Lew M. Atkins, Assistant Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

Donald R. Battles, Assistant Naval Constructor, U. S. N., Fore River Shipbuilding Co., Quincy, Mass.

Lee S. Border, Assistant Naval Constructor, U. S. N., Navy Yard, Mare Island, Cal.

Frederic G. Coburn, Assistant Naval Constructor, Navy Yard, Mare Island, Cal.

Waldo P. Druley, Assistant Naval Constructor, U. S. N., Navy Yard, New York, N. Y.

Edwin O. Fitch., Jr., Assistant Naval Constructor, U. S. N., Navy Department, Washington, D. C.

Paul H. Fretz, Assistant Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

Julius A. Furer, Assistant Naval Constructor, U. S. N., Navy Yard, Charleston, S. C.

Charles A. Harrington, Assistant Naval Constructor, U. S. N., Navy Yard, Portsmouth, N. H.

Sidney M. Henry, Assistant Naval Constructor, U. S. N., Navy Yard, New York, N. Y.

Herbert S. Howard, Assistant Naval Constructor, U. S. N., Navy Yard, New York, N. Y.

Parker H. Kemble, District Manager, Edison Electric Illuminating Co., 360 Pearl Street, Brooklyn, N. Y.

Edwin G. Kintner, Assistant Naval Constructor, U. S. N., Navy Yard, Norfolk, Va.

Harry G. Knox, Assistant Naval Constructor, U. S. N., Navy Yard, Boston, Mass.

Emory S. Land, Assistant Naval Constructor, U. S. N., Navy Yard, New York, N. Y.

Roy W. Ryden, Assistant Naval Constructor, U. S. N., Navy Yard, Portsmouth, N. H.

Ross P. Schlabach, Assistant Naval Constructor, U. S. N., Navy Yard, Charleston, S. C.

Clayton M. Simmers, Assistant Naval Constructor, U. S. N., Navy Yard, Puget Sound, Wash.

Townsend J. Smith, T. S. Marvel Shipbuilding Co., Newburg, N. Y.

George C. Westervelt, Assistant Naval Constructor, U. S. N., Navy Yard, New York, N. Y.

John W. Woodruff, Assistant Naval Constructor, U. S. N., U. S. Naval Station, New Orleans, La.

*For Juniors* (4).

Lawrence E. Chapman, Massachusetts Institute of Technology, Boston, Mass.

Torbjörn Hermanrud, Draughtsman, Fore River Shipbuilding Co., Quincy, Mass.

John D. Schmidt, Student, Webb's Academy, New York, N. Y.

A. Harold Jansson, Draughtsman, Experimental Model Basin, Navy Yard, Washington, D. C.

THE PRESIDENT:—You have heard the list of members, associates, juniors, and life members that has been presented to you. If a ballot is demanded, it will be taken, but the gentlemen named have been recommended by the Council unanimously. What is your pleasure? Those in favor of adopting the report of the Council, and declaring these certain gentlemen to be members of the several grades, please say "Aye;" contrary, "No." It is carried unanimously, and the gentlemen named are now declared members, associate members, juniors, and life members of the Society.

The Secretary will now read the proposed amendments to the By-Laws recommended by the Council.

THE SECRETARY:—In accordance with Article VII of the Constitution and By-Laws of this Society, the following amendment was prepared by the Executive Committee, and has been signed by more than ten members, and is presented for approval or disapproval by the Society as a whole.

Proposed Amendment to Paragraph 5, Section 3, Article II, which refers to junior members:

Add the words: "When they are twenty-six years of age, they shall be offered the option of being transferred to active or associate membership, if they duly qualify; but if they do not accept such offer or do not qualify they shall be dropped from the rolls of the Society."

THE PRESIDENT:—This amendment is now before you, and must be adopted by a two-thirds vote—by ballot, if a ballot is demanded. What is your pleasure?

It was moved, seconded and carried unanimously that the proposed amendment be adopted without a ballot.

THE PRESIDENT:—The amendment is therefore adopted, and will be henceforth in force.

## PRESIDENT'S ADDRESS.

I thank you again for the great honor you have conferred upon me. You have placed me in the position herefotore occupied during the existence of this Society by two men most distinguished in their careers—Clement A. Griscom, who stands foremost among those interested in American shipping, and Francis T. Bowles, Naval Constructor, Constructor-in-Chief with rank of Rear Admiral, and now the head of one of the large shipbuilding plants of the United States.

These gentlemen gave a great deal of thought and time in their endeavors to organize and carry on this Society, and to their endeavors the success of the Society has been very largely due.

We endeavored to have these distinguished Past Presidents at this meeting, but Mr. Griscom had previously made important engagements which prevent his presence, and, as you are all aware, Admiral Bowles has met, in the recent loss of his son, a great bereavement, in which he and his family have, I know, your heartfelt sympathy.

The Past Presidents have a reputation which seems to me difficult to live up to, and I can only assure you of my intended conscientious attention to your interests, with the hope that they may not be entirely in vain, and I trust that at the completion of my term of office I may at least deserve the centuries old commendation: "Well done, good and faithful servant!"

I congratulate the Society on its membership, which will at this meeting be increased by at least forty members. This more than offsets the losses due to deaths and resignations, which amounted to twenty-six during the past year.

There are yet a number of young men in our shipyards and engine building establishments to whom our proceedings would be of great advantage, and it is desired that you shall bring them into our fold for their benefit as well as ours.

The moderate dues hardly pay for the publishing of the proceedings, and the better and more numerous the proceedings the greater the cost. I suggest that for the future benefit of the Society such of you as may deem it feasible and wise shall become Life Members, thus creating a fund which, as the years go by, will add to our regular income.

The Treasurer's report as printed shows clearly our financial condition, and at its meeting yesterday the Council wisely reduced some of the nominal assets, as was reported to you.

There have been no special advances in the art and science of ship and engine building, for at the present time we seem to be in a period of development. Progress is being made in the application of a combination of reciprocating and turbine engines for marine use, and of a combination of fast running turbines with gearing for slow going vessels. Further developments in these directions are awaited with great interest, as will be also the use of producer gas and gasoline engines of larger units than have heretofore been tried.

Our Navy, in importance and quality, and in size of ships, if not in number, compares favorably with the navies of the world.

Following in some respects the example of the later great merchant ships built abroad, battleships have increased in dimensions, displacement, speed and ordnance to a remarkable degree. In this connection, the first paper of to-day's meeting, written by our distinguished Honorary Member, Sir William White, whose career as Naval Constructor in England is so well known, presents views on the growth of war vessels and on the eternal question—guns versus armor, armor versus guns. This paper will particularly interest not only those of you who are responsible for our Navy, but those who are directly responsible for the vessels of all other navies. I commend it to your careful consideration.

There has been a great development in the past few years in that branch of mechanics which may be termed aeronautics. The improvements in both dirigibles and aeroplanes, particularly in the latter, have been marvelous. It is but five or six years since man made a flight of a few feet with a heavier-than-air machine. During the past year flights of distance and altitude have been made that were hardly dreamed possible but a short time ago. To what uses these wonders of the air may come it is dangerous to predict, more particularly as to their limitations, for in the light of the achievements of the past quarter of a century it is a bold man or foolish one, as you may look at it, who says that any particular accomplishment is impossible.

Unfortunately for true scientific progress, the recent aeronautic exhibitions have been too much of the hippodrome order to command our highest respect.

Though submarines have accomplished great feats, experiments are still being made to add to their efficiency.

Oil fuel applied for marine use has passed the experimental stage. Excellent results have been accomplished and many advantages proven. Where coal is scarce and oil is plenty, oil fuel is naturally used to great advantage; but the storage, the safety in use, and the procuring of oil of the same quality at all times, are yet sufficiently experimental to warrant the study still given to this subject where coal is cheaper than oil.

So in all the varied branches of our professions we are still achieving, still pursuing.

In the beginning of this year, this Society was honored by the Institution of Naval Architects of England by its invitation to join in a Jubilee Meeting in London, celebrating the Fiftieth Anniversary of the founding of that most distinguished Society. As you know too well, the death of their beloved King Edward VII compelled a postponement of their celebration, and with that great people, in common with the rest of the world, this nation mourned.

We are now advised that the Jubilee Meeting will be held in London commencing July 4 next, and I can assure you that those who may be so fortunate as to be able to accept their cordial invitation will receive a warm welcome. May many of you go.

One subject near to our hearts is that of the American merchant marine. "Hope deferred maketh the heart sick," and the hopes deferred in this matter have almost caused heart failure.

Protection has been the leading theory and practise of great political parties and has led the country at large into great prosperity. Everything going into a ship has been amply protected, excepting the building thereof. The very protection given various materials and labor in the manufacturing of them has so added to the cost of building ships that it is impossible to compete with the cheaper labor and materials of foreign countries, and yet the word "subsidy," substituted for the word "protection," has for some curious reasons become almost disreputable, and the cry is raised—Shall we spend public money for the benefit of a few shipbuilders? Had this thought obtained to any degree in relation to the many large industries of the country, so well fostered by the tariff, there to-day would have been a dependence on foreign manufacturers truly deplorable, and a billion dollar Congress impossible.

One great difficulty with the subject of legislation tending to increase the merchant marine is that the advocates, though they see clearly the great need and the public advantage of an adequate merchant marine, have such varied methods of accomplishing the desired result.

For my own part, I have come to the conclusion that a subsidy for establishing lines to South America or other specific countries, that extra payments for carrying mails and for tonnage and speed, in short, that the various methods of special rewards are entirely futile; and that there only remains for us to go back to the practise of our forefathers and establish discriminating duties. This is not the

time for arguments on this question, and opinions may change. I know that strong men differ, but we are like the children in Maeterlinck's fairy play looking in various directions for our particular "Blue Bird" and finding it not; and some day, not too far off I trust, the people of this great nation with its thousands of miles of seaboard, with its great protective Navy which, in the final analysis, must depend upon a Merchant Marine, with its many and large productions from the soil, and from its varied manufactures, will realize the supreme importance of having ships and yards in which to build them, will realize that we are to-day deliberately passing to foreigners annually enormous sums which should be earned by our own citizens; and they will come to themselves, will unite on the right course, will demand from their representatives a change in the present condition, and they will get it. So be of good cheer. Let your hearts faint not.

One of the best features of these Society meetings is the social side of them. Here we gather annually, some of you rivals in intense competition during the remainder of the year, but here friends, renewing acquaintances and reviewing accomplishments. I know of no better way of avoiding misunderstandings, heartburns and ill-feelings than getting together in these meetings, and I am proud to say that, in this particular, this Society has been exceedingly fortunate.

Let me urge you to continue this good course. Let the younger members not hesitate to make themselves known to the elders and the elders not forget their own struggles in youth. Be ready to extend helpful thoughts to each other, and remember, though you cannot see the growth of shipbuilding as you desire, you are members of a profession second to none in building material things. Your numbers may be comparatively small, but you combine in yourselves the knowledge and the skill of all of the other special mechanical and engineering societies, and your problems are more difficult to solve. (Applause.)

THE PRESIDENT:—The next in order is the reading of a report of the Special Committee appointed by the Council last year, of which Admiral Capps is Chairman, and I will ask the Secretary to read the Report.

## REPORT OF SPECIAL COMMITTEE.

NOVEMBER 16, 1910.

SIR:—On November 19, 1909, during the last Annual Meeting of the Society of Naval Architects and Marine Engineers, the following resolution was unanimously adopted as a partial recognition of the eminent services to the Society of its retiring President, Rear-Admiral Francis Tiffany Bowles.

"*Resolved*, That the Society desires to place on record its regrets that the President was compelled to be absent from this meeting, and it further desires to

express it great appreciation of the work he has done for its advancement since its first meeting sixteen years ago; also that it is the sense of this meeting that a Committee be appointed by the Chairman to prepare and present a more formal and complete recognition of his services, at the next meeting, which it is earnestly hoped he will attend."

In the exercise of the authority conferred upon you by the above noted resolution, a committee was appointed, composed of the undersigned members of the Council, for the purpose of formulating and presenting to the Society at its next annual meeting the "more formal and complete recognition of his services" contemplated in the resolution above noted.

At a preliminary meeting of this Committee it was decided unanimously to submit the Committee's draft of the formal resolution for the action of the Society at its forthcoming meeting on November 17, 1910, and to make immediate recommendation to the Council that there be presented to Admiral Bowles, by his colleagues of the Council, as a mark of their official appreciation and personal esteem, a suitably inscribed loving cup. This suggestion of the Committee met with prompt and cordial response from the individual members of the Council, and it is proposed to make the presentation of the loving cup to Admiral Bowles on Friday, November 18, on the occasion of the Annual Banquet of the Society.

The services of Admiral Bowles to the Society of Naval Architects and Marine Engineers, in connection with its formation and development, are too definitely indicated in the proceedings of the Society and are also too well known to its individual membership to require any extensive enumeration, even for purposes of historical record. It seems most fitting, however, that formal mention be made of the facts that he was one of the principal organizers and incorporators of the Society, was the first Chairman of its Executive Committee, and served for a period of five years as its Secretary, and more than five years as its President. Such a record of accomplishment speaks for itself, and any added force which might be given through formal expression by this Committee is believed to be best conveyed by quoting some remarks made by the late lamented Commodore Loring, one of the founders and original Vice-Presidents of this Society. These remarks were made by Commodore Loring on the closing day of the First Annual Meeting of the Society, in proposing a vote of thanks to Admiral Bowles, and were as follows:—

"MR. PRESIDENT AND GENTLEMEN:—There has devolved upon me the very agreeable task of proposing a vote of thanks to one whose happy idea is responsible for the pleasure and profit we have derived from the inaugural meeting of this Society.

"While individual commendation is, in general, to be deprecated, historical accuracy is never amiss, and the first volume of the published transactions of this Society would not be complete did it not contain a formal recognition of the services

of one whose felicitous conception, aided by your generous and united efforts, has culminated in such gratifying results.

"As Colonel Stevens so aptly pointed out at the banquet last evening, our Society now needs no sponsor, but we must not forget that this success, thorough and incontrovertible though it be, has been the result of studious thought and painstaking care.

"In all the work of inception and execution, the master mind and guiding hand have been those of Naval Constructor Francis T. Bowles, and it is to his unerring skill and tact and untiring devotion that we are indebted for the formation of a Society which will always be a means of professional advancement, and which cannot but prove a potent factor in the reawakening of general interest in our shipbuilding development, and in the ultimate attainment of that maritime supremacy which once was ours, and must in the future inevitably return."

The unusual tribute to Admiral Bowles made by Commodore Loring in 1893, in proposing the Society's vote of thanks to that gentleman, was seconded by Colonel Stevens and unanimously endorsed by the Society. In the years of development of the Society which followed, the subject of this tribute, through his earnest, loyal, and devoted service to its best interests, has not only justified the original tribute but placed the Society under renewed obligations which have found appreciation in his election to the highest office in the gift of his colleagues. As a further mark of appreciation of the services of its late President, the Committee recommends to the Society, for its approval, the following resolution:

"*Resolved*, That the Society of Naval Architects and Marine Engineers desires to avail itself of this first opportunity, since the completion of his term of office as President, to give formal expression of its appreciation of the services of Rear-Admiral Francis Tiffany Bowles, whose skill, tact, and untiring devotion, first as organizer, and later as Secretary and President, contributed in so conspicuous a degree to the development of the Society and its present assured position among scientific institutions; and that in furtherance of the foregoing expression of appreciation, the President is directed to have this resolution and the accompanying report of the Committee recorded in the minutes of the Society, and a copy thereof suitably engrossed and forwarded to Admiral Bowles.

Very respectfully,

W. L. Capps, *Chairman*,
Stevenson Taylor, *Ex-Officio*,
E. A. Stevens,
Geo. E. Weed,
Andrew Fletcher,
W. J. Baxter.

The President,
*Society of Naval Architects and Marine Engineers.*

THE PRESIDENT:—You have heard the report, gentlemen. What is your pleasure?

It was moved and seconded that the report be accepted.

THE PRESIDENT:—It has been moved and seconded that the report be accepted and that the resolutions be suitably engrossed and sent to the Past President. I ask you to give a rising vote on this question. Those in favor will please rise.

All the members present arose.

THE PRESIDENT:—As I knew it would be, the vote is unanimous, and I am sure Past President Bowles will receive this resolution with a great deal of pleasure. He has promised to be with us at our banquet to-morrow evening, and I trust you will all be there to meet him.

The next in order is the reading of the papers. I call for the reading by Mr. D. H. Cox of the paper on "Notes on the Armaments of Battleships," by Sir William H. White, K. C. B., F. R. S., D. Sc., D. Eng., LL.D., Honorary Member.

Mr. D. H. Cox read the paper.

# NOTES ON THE ARMAMENTS OF BATTLESHIPS.

By Sir William H. White, K. C. B., F. R. S., D. Sc., D. Eng., LL. D., Honorary Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

The Council of this Society have honored me by making the request that I should contribute a paper to the Proceedings. After full consideration it has appeared that, in existing circumstances, it may be of interest to members to attempt a summary of the principles which should regulate the armaments of modern battleships. Wide and deep differences of opinion prevail in regard to this subject; as a consequence it may be anticipated that conclusions which the writer has reached will be challenged and declared to be unsound. Nothing but good can result from discussion and criticism when they are conducted on proper and temperate lines as they will be in this Society; and consequently the writer has not hesitated to express freely his dissent from doctrines which other persons have set forth in dealing with the subject, and will not object to equally free criticism being made of the following statement of principles to which he has been led by study and experience during the forty-three years that have elapsed since he first joined the Constructive Department of the British Admiralty.

One fundamental idea has governed the armaments of warships in all ages: viz., the desire to provide means of offense which will enable a ship making an attack to put her enemy "out of action" in the shortest possible time and ensure the least possible damage to the attacking ship during the conflict. Until armor was first used for defensive purposes, about half a century ago, there was universal agreement with the doctrine that "an active and powerful offense constituted the best means of defense." Since that date this doctrine has been somewhat obscured, no doubt, by the attention devoted to improved methods of manufacturing armor, to rival systems of distributing protective materials; by the never-ending struggle between the attack and the defense—guns and armor—and by the development of under-water attacks—locomotive torpedoes and torpedo vessels, submarine mines and submarines. It may be admitted also that, under modern conditions, an active offense is no longer the only means of defense; but, on the other side, it cannot be denied that an active offense is still and always must continue to be the best means of defense. It gives the greatest assurance of victory—in other words the greatest probability of putting an enemy "out of action."

This old phrase continually occurs in descriptions of naval battles of the past, and it is no less applicable under modern conditions than it was in the days of sailing ships and smooth-bore guns, or even in that more remote period when naval warfare was carried on by galleys propelled by oars and manned by soldiers. Victory never has depended and never will depend entirely upon the destruction or capture of an enemy's ships, but upon their being brought into a condition of incapacity to continue the struggle—that is to say, being put out of action. That result may be attained in many ways, but it must be reached in some way before victory is secured. All naval history confirms this statement; it is, in short, a truism. Looking back upon the great wars of the eighteenth and beginning of the nineteenth century it is seen that ships were put out of action by the destruction of or serious damage to their means of propulsion, by injury done to their mobility and maneuvering power; by being set on fire; by slaughter of their crews; by loss of morale; by panic arising from accident or damage which prevented continued utilization of existing means of offense; by overpowering or seriously injuring the armaments, and in other ways that need not be particularized.

This statement of the case applies primarily to circumstances affecting individual ships, and it designedly omits reference to the supreme influence which naval tactics may exercise upon the result of a fleet action, or to the skill of a commander in concentrating upon a portion of the enemy's fleet an overwhelming attack. When the tactician has done his best, it still remains true that the chief aim in a naval engagement must be to put an enemy's ships "out of action" as quickly as possible, and that sinking or destruction of ships is not necessary to secure that result, although it may be an accompaniment of victory.

From the point of view of this paper, the question to be considered may be stated, therefore, as follows:—What description of armament is likely to prove most effective for speedily putting out of action modern battleships, having regard to existing materials of construction, structural arrangements, armor defense, means of propulsion and maneuvering; as well as to the characteristic qualities of guns, projectiles, explosives, torpedoes and mines now available for use? In considering this question it will be assumed that, in addressing this Society, there is no need to recapitulate the remarkable advances which have been made in all these features of war-ship construction during the last half century. The facts are on record, and the existing situation is well known to members.

Certain features of the problem may also be assumed to lie outside the field of discussion. It is generally agreed that future naval actions

will probably be fought at longer ranges than have been adopted in the past. The main reasons for this increase in fighting range are to be found, on one side, in the development of locomotive torpedoes and the increase of their speed, accuracy, and effective range; while on the other side stand no less important improvements in naval gunnery—including guns, propellants, projectiles, explosives, range-finders, sights and means of control. Nor can there be any dispute as to the fact that increase in gun-caliber in association with a constant muzzle velocity secures greater flatness of trajectory, and greater accuracy of fire, as well as superior maintenance of energy at long ranges. But when general statements of this nature are closely examined, differences of opinion on practical matters are found to exist among men equally entitled to a respectful hearing, and these differences sensibly influence their choice of armaments.

## LONG FIGHTING RANGE AND SECONDARY ARMAMENTS.

In regard to the probable fighting range for future naval actions there are marked differences of opinion. While all agree that it is likely to be greater than heretofore, two distinct schools of thought exist as to the minimum range likely to occur in practise. One of these asserts that an extremely long range will be chosen and maintained by commanders whose fleets possess greater speed and whose ships are armed on the "single-caliber, big-gun" principle; and it is argued that at this great range vessels so armed will be able speedily to put out of action an enemy's ships which individually carry fewer big guns, although these may also possess powerful and well-protected secondary armaments. These secondary armaments, it is urged, would be of no practical service at very long range; because of an alleged inferior accuracy (due to more curved trajectories traversed by their relatively small and light projectiles), their proportionately greater loss of energy as ranges increase, and their presumed ineffectiveness because of their lack of power to penetrate armor of moderate thickness, their alleged less proportion of hits to rounds fired, and the small bursting charges carried by their shells.

The other school maintains that, although actions may be begun at very long ranges on occasions when atmospheric conditions are favorable, average conditions of weather at sea will not favor that kind of attack nor make its results decisive. They give reasons for the belief that when an issue is joined, with the full intention to reach a decisive finish, it is practically certain that closer ranges will be reached; and they insist that the choice of armaments ought not to be governed by a set of assumptions

which relate exclusively to extreme ranges and are subject to the continued efficiency of comparatively delicate sights and range-finders as well as apparatus for controlling gun-fire. In their judgment it is desirable to associate with big guns a powerful secondary armament of quick-firing guns, adequately protected and so placed as to be efficient both in horizontal command and in height above water, while free from interference arising from independent firing of heavy guns.

In support of this advocacy of good secondary armaments it is stated that modern types of battleships, including those on which armor defense has been most developed, still contain many vulnerable points, injury to which will seriously interfere with the fighting, maneuvering and steaming capability, the transmission of orders from conning-towers and control stations, signalling and other operations which considerably influence fighting efficiency. It is noted that more than one-half of the length of heavy guns is permanently exposed and unprotected. Cases have occurred in action where these unprotected portions have been injured, the heavy guns having been put out of action by the fire of light guns which were impotent at the fighting range against armor of moderate thickness. It is also maintained that the small height above water to which the hull armor rises, and the large unarmored areas of the sides above water, must involve serious risks to a considerable number of recent battleships should they be subjected to attack by a large number of 6-inch quick-firing guns using high-explosive bursters and common shell. The "volume of fire" obtainable from such quick-firing guns would, it is considered, inflict great damage to the thin steel-plating above the armor, and so permit considerable quantities of water to find access to the interior of the ship above the protective deck, although the hull armor was left intact. Such an entry of water might seriously prejudice stability or produce objectionable "list" and change of trim, even if it did not pass below the protective deck; but there would also be the danger of large quantities of water finding a way into hold spaces and there accumulating.

These anticipations of trouble, of consequent reduction of stability, loss of maneuvering power, diminished speed and lessened mobility, are treated by the other side as unlikely of fulfilment. In support of this view it is urged that, although at short or moderate ranges the 6-inch gun makes good practise and scores a high percentage of hits to rounds fired in comparison with the percentage attained by larger guns, yet at long ranges the percentage of hits to rounds becomes comparatively small. Consequently it is considered that injuries of the kind assumed to be produced by the fire of secondary armaments are not likely to be either serious or

extensive. There is obviously room for difference of opinion in regard to such matters and the proper method is to trust to experience when attempting to reach a decision. When tested on a proof ground, with guns and targets fixed and ranges known, the percentage of hits to rounds fired will undoubtedly become greater at long range as the caliber of guns is increased. These conditions, of course, do not represent those which would occur in a sea fight, between fleets or between single ships, moving rapidly in relation to one another, and commonly in circumstances which will be accompanied by rolling or pitching of the gun platforms. It is not possible in peace time to imitate all the conditions of war; in particular the disturbing influences which necessarily arise when a warship is fired at by an enemy while making an attack cannot be represented. But there is in existence a considerable body of information based upon "battle-practise" at long ranges. These facts have not been published in detail nor are they likely to be. The writer has, however, been assured by naval officers of great experience possessing full and accurate information of this kind, who have carefully analysed results of firing at very long ranges, that the percentage of hits to rounds fired obtained with 6-inch guns under service conditions at sea compares favorably with and is not inferior to the percentages obtained with guns of larger caliber. Furthermore he has good reason for the belief that actual trials do not confirm the objection raised to "mixed" armaments on the ground that the simultaneous discharge of guns of different calibers must be accompanied by diminished efficiency in the control of fire and in the proportion of hits to rounds made by guns of different calibers. If these conclusions be true—and the writer is convinced that they are so—then it is unquestionable that even at long ranges the secondary armaments of battleships will be capable of delivering a "hail of fire" against an enemy, and of exercising an important influence on the result of an action.

Published accounts of naval engagements during the Russo-Japanese war also emphasize the importance attaching to attacks made by efficient and well-handled secondary armaments carried by Japanese ships. It is probable that the deep-laden condition of Russian ships at Tsushima tended to increase sensibly the prejudicial effects of fire from the lighter guns of the Japanese fleet; but after making full allowance for this feature it appears proven that considerable danger must always attend the extensive damage to unarmored superstructures which quick-firing guns of moderate caliber can inflict even at long range. What the "volume of fire" from such guns involves in damage done to signalling apparatus, control appliances and the general working of a ship in action, Captain Semenoff has graphically described. What it may do in making ships

unmanageable or in temporarily destroying the command of maneuvering capability was demonstrated at Tsushima and in the battle of 10th August, 1904, off Port Arthur. Under the terrible hail of projectiles and of fragments of shells containing high explosives it has happened and will happen again that a "joint in the harness" is discovered and the ancient story of the "bow drawn at a venture" is repeated. The Japanese authorities, who may be supposed to have all the facts of the war in their possession, and who are certainly capable of analysing them and drawing therefrom lessons for guidance in future practise, have never departed from the use of powerful secondary armaments. Personal conferences with leading Japanese authorities on naval matters enable me to say that they attach the utmost importance to the association of such armaments with guns of large caliber. In fact the trend of naval opinion throughout the world during recent years has been against the perpetuation of the system which discarded all guns except those of large caliber and 3-inch guns for use against the attacks of torpedo vessels. Consequently there is a danger of appearing "to flog a dead horse" by further advocacy of secondary armaments on this occasion, and no more need be said thereupon.

As to the most suitable numbers and calibers of guns making up the secondary armaments of modern battleships little need be added. There are obvious objections to the employment of many calibers, each requiring special ammunition and making separate control desirable. In some ships guns of 6-inch, 4.7-inch, 3-inch and smaller calibers have been mounted. Such a multiplication of calibers appears both unnecessary and objectionable. Probably the explanation is to be found in an intention to use guns from 4.7-inch downwards as an active defense against the attacks of torpedo vessels, and to supply 6-inch guns as auxiliaries to the 12-inch guns in action. The writer has long advocated a simpler arrangement which, in his judgment, would fulfil all requirements, and ventures to quote remarks on this head made at the Institution of Naval Architects a few months ago:—

"The ideal armament, to my mind, is that which embodies a certain and not an extravagant number of heavy guns associated with a considerable battery of 6-inch guns. It does not seem to me a difficult matter to supply these 6-inch guns with ammunition which shall be efficient when used against attacking torpedo vessels. If anything in addition to such a secondary armament of 6-inch guns is wanted I should say 'man-killing' guns capable of very rapid fire mght be used for sweeping the decks of torpedo vessels; they could be placed and fought in almost any position and would require only shield protection."

Twenty-six years ago the writer, in conjunction with the late Lord Armstrong, worked out a design for a vessel in which ammunition of the special kind mentioned was provided for guns of 5-inch to 6-inch caliber for use against torpedo craft. It has been reported recently that experiments have been made with shrapnel fired from 12-inch guns as a possible means of repelling torpedo attacks. If this be true the principle advocated has been carried to an extreme which will not commend itself generally, but the experiments constitute a virtual confession that 3-inch guns are not sufficiently powerful to deal effectively with modern torpedo vessels. That view of the matter has been confirmed by the adoption of 4-inch and 4.7-inch guns instead of 3-inch in ships of recent design; while 6-inch guns are now recommended for defense against torpedo vessels in quarters where 3-inch guns were advocated four or five years ago as the only auxiliary armament required. The compass has been "boxed" in a very short time, and without any war experience to justify the change of opinion.

The main reason for preferring a caliber of about 6 inches is that experience proves projectiles of about 100 pounds weight to be the maximum which can be "man-handled" continuously and rapidly; while accuracy of fire even at long range can be combined with rapidity of discharge and remarkable effectiveness against the lightly armored, unarmored and vulnerable points of warships. Personally, I have always maintained the view that these quick-firing guns, their crews and the supplies of ammunition, should have a reasonable amount of armor protection against the fire of similar guns carried by an enemy. In designs for which I was responsible more than twenty years ago, in which the earliest 6-inch quick-firing guns were mounted, such protection was provided. Nothing that has since occurred has shaken that conviction, and my opinion remains fixed that the secondary armament should be not merely available for use in repelling torpedo attacks but should be used in battle and be regarded as a valuable auxiliary to the heavy guns. The disposition of the 6-inch guns should be of a character that will effectively fulfil both these functions. It is not difficult to secure that result in designing warships, and to place the 6-inch guns so that they shall not be hampered or interfered with by the fire of the heavy guns, provided that the number of the heavy guns carried in a ship is not made excessive.

## THE NUMBER OF HEAVY GUNS TO BE MOUNTED.

Turning to the consideration of what constitutes a reasonable number of heavy guns for the principal armament of a modern battleship, it will

suffice on this occasion to re-state the writer's conclusions and to briefly summarize the reasons therefor. These conclusions are admittedly open to debate and other views may be maintained on the basis of solid argument. The case is necessarily one for compromise, and therefore for difference of opinion as to the best course to be pursued.

There are two positions for heavy guns which by common consent confer supreme advantages, and are always utilized. These positions are at the center line of the deck: one commanding right-ahead fire, with large arcs of horizontal training reaching well abaft the beam on each side; the other possessing corresponding command right astern and over large arcs of training reaching well before the beam. Until the Michigan and South Carolina were designed it was the general practise to mount one or two heavy guns—two in nearly all cases—in each of these positions. Superposed turrets on one turntable were tried in some cases, and 8-inch guns were mounted in the upper emplacement; but this practise did not find much favor and may be considered to have dropped out of use. It was a new and bold departure in the Michigan and South Carolina to place two turrets in each of the supreme positions, and to arrange for firing the guns in one turret over the top of the other turret. That arrangement proved successful, however, and has been largely adopted in recent ships of all navies. When associated with the mounting of guns in pairs this system permits the effective use of eight heavy guns; if three guns are mounted in each turret then twelve heavy guns can be given equal arcs of command, and all the guns can be used on each broadside.

The writer has always favored and still favors the system of mounting heavy guns in pairs. French designers long preferred separate mountings for single heavy guns, and placed two gun stations amidships—one on each side. The French system was tried in the British armored cruisers Imperieuse and Warspite, and as the result of trials it was not repeated; the French themselves subsequently abandoned the arrangement. Twin-mountings were universally employed for a long period, and, in the writer's judgment, that plan embodies a reasonable compromise. Considerable economy is thus effected in the weight of the mountings and armor protection for a pair of heavy guns as compared with what is needed with separate mountings for each gun; and although the risk of simultaneous disablement of two guns is necessarily incurred when they are carried on a single turntable and within the same armored station, that does not seem to be an undue risk. When three guns are mounted on one turntable and exposed to similar risks of simultaneous disablement then, in the writer's judgment, too many "hostages are given to fortune," and economy in weight

of protective material and mountings has been carried too far. Actual trial will determine whether or not it is possible to maintain the same rapidity in loading and firing individual guns in a triple turret as can be obtained when two guns are mounted in one turret, and Italian naval authorities before deciding in favor of triple turrets probably satisfied themselves on this point. Italy has made many successful new departures in warship design, and will work out this problem thoroughly. The results will have great interest for all engaged in warship construction; but even if they prove satisfactory under peace conditions and as to rate of fire, only war experience can determine the crucial point as to the risk of simultaneous disablement of three guns mounted on a single turntable. The approximate allowance hitherto made for triple as compared with twin turrets is understood not to exceed an increase in diameter of about ten per cent.; in some cases it has been less. Obviously it would be reasonable in triple turrets to make provision for stronger armor protection and for larger margins of strength in machinery and structure in order to meet special risks, and to lessen the possibility of disablement in action. If this were done the relative weights involved in the triple as compared with the twin arrangement would be considerably increased.

In passing one may remark that there is always a danger lest the desire to keep down weights of protective materials on heavy-gun stations should lead designers to accept relatively weakened structures and supports to armor and smaller clearances between fixed structures and revolving parts than would afford reasonable provision for safety and for continued efficiency in working when heavy blows are delivered, in action, upon the armor forming barbettes, shields or turrets. This feature in design has always received close attention in my own practise; and the dimensions and weights of structures, armor and mechanisms have not been reduced, nor have any known or probable risks been accepted, in order to minimize weight. Having regard to the vital importance of the continued efficiency of heavy-gun armaments, and to the enormous weights and cost involved in installing and protecting such armaments even when dimensions are minimized, it seems preferable to err on the side of large margins of safety rather than to seek the irreducible minimum—the determination of which is not an easy matter, even for those most fully informed as to the results of peace experiments and past naval actions.

For more than twenty years the heavy guns of most battleships continued to be four in number, and in nearly all cases they were mounted in pairs on the center line of the deck at the two important positions above described. In connection with the introduction of the latest types of

battleships—usually described as "Dreadnoughts"—a necessity arose for finding other positions for heavy guns. Ten or twelve such guns have been usually thought desirable; thirteen guns are to be carried in ships now building. Consequently three or four additional gun stations have had to be provided, and large hold spaces have been devoted to the stowage and supply of ammunition immediately below each turret. Different dispositions of heavy-gun stations have found favor, not merely in different navies, but in successive ships of the same navy. In these circumstances it becomes obvious that no fixed principles have been established or generally followed hitherto in disposing heavy-gun armaments. It is unnecessary to describe in detail various arrangements adopted in recent ships, because they are well known to members of this Society; but mention may be made of certain salient features which illustrate the diversity of views that have prevailed.

In many cases history has been repeating itself; arguments which were familiar thirty or forty years ago have reappeared and have been treated as novelties. Widely differing estimates have been formed in regard to the relative importance attaching to "end-on" and broadside fire. In the earlier French disposition—in which two heavy guns were mounted forward and aft on the center line of the deck as bow and stern chasers, and two others in positions on each broadside (nearly amidships) which enabled them to be fired directly ahead or astern—"end-on" fire was treated as of equal importance with broadside fire. Three guns were available on each broadside and three guns could be fired either ahead or astern. In ships of the "central-citadel" type (designed about 1873–78) four heavy guns were carried in two turrets which were placed *en echelon* nearly amidships, and it was possible to fire all four guns parallel to the keel, either ahead or astern. Each pair of guns had 180 degrees of training on the broadside whereon they were placed, but on the other broadside these guns had only a very limited arc of training. In these vessels, therefore, "end-on" fire was theoretically superior to broadside fire. Experience showed, however, that superstructures erected above the upper decks—primarily to limit the effect of "blast," when the guns were fired parallel to the keel-line or at large arcs of training from the beam—imposed serious limitations and disadvantages against a moving target placed nearly ahead or astern. The echelon disposition was, therefore, abandoned and a return was made to the earlier plan which mounted four guns in two commanding positions forward and aft on the middle line of the deck.

During the last five years we have seen both the old French disposition and the echelon arrangement reproduced (in principle) in new designs,

only to be abandoned in later designs, in some cases before practical experience had been gained with the arrangement which was abandoned. Now there is a marked disposition to place all the heavy-gun stations at the center line of the deck, so that all the guns may be available on both broadsides. This is a return to a disposition adopted in the earliest British turret ships built nearly half a century ago. The Royal Sovereign (1862) and the Prince Albert which followed immediately after her each had four turrets so placed. It may be noted that the United States Navy took the lead in this last movement, and further has the credit of demonstrating the possibility of associating powerful bow and stern fire with the maximum of broadside fire over large arcs of training, by placing some turrets higher than others and firing over the lower turrets on certain bearings.

## "END-ON" AND BROADSIDE FIRE.

Advocates of "end-on" fire assert that an attacking ship which is end-on to an enemy presents to her fire a target of which the projected area (on a vertical plane) has, for its largest dimension, the extreme breadth of the ship and for its height the height of her uppermost deck; so that the chance of hitting effectively is diminished greatly as compared with broadside attack. This statement overlooks important conditions, and is therefore misleading. A ship attacking end-on must present to the fire of an enemy a horizontal target of which the greatest dimensions are the full length of the vessel, and (transversely) her extreme breadth. Consequently errors in elevation of guns which the enemy may make are less likely to result in missing this long horizontal target than would be the case if corresponding errors were made when firing at a target of which the greatest dimension was the extreme breadth of a ship lying broadside on to the line of fire. No one can deny that the minimum of defense of vital parts of battleships—especially against "dropping" fire at long ranges—is to be found in the resistance offered by protective-deck plating, and not in the strength of vertical side armor. Nor can it be doubted that even in single-ship actions it would hardly be possible for a combatant to maintain for long the assumed "end-on" position; while in fleet actions no commander could possibly effect a similar object with a large number of ships by any conceivable tactics, if engaged against a skilful and mobile enemy. If a choice has to be made, therefore, between highly developed broadside and end-on fire it seems reasonable to give precedence to the former. This has been done in the majority of recent battleships; but it is also reasonable—having regard to great and rapid variations unavoid-

ably occurring in the relative bearings of ships in action—to develop end-on fire to a reasonable extent. The compromise represented in the Michigan class now secures wider acceptance and is likely to become more generally adopted.

No difference of opinion exists as to the necessity for giving the largest possible arcs of horizontal command to the fire of heavy guns, so that in action they may be kept bearing on an enemy for the longest attainable periods as his relative position rapidly changes. When this principle is applied in working out the disposition of guns for a new warship one soon encounters numerous as well as serious limitations and finds that the difficulties in securing large arcs of training increase with increase in the number of gun stations. In many cases the attempt to mount a large number of guns and to give to each gun considerable arcs of training has involved serious risks of injury being inflicted on neighboring guns and their crews, when fire is delivered at or near the extremes of assumed arcs of training. Attempts are made, of course, to minimize or to prevent such risk of injury; but so-called "safety appliances" are usually of a delicate and elaborate nature and not unfrequently are intended to be automatic in action. One may be permitted to doubt whether, in the heat of action, these appliances will always fulfil their intended purpose; and it appears desirable when arranging armaments, to secure practical non-interference of gun with gun, even if that course involves a decrease in the number of heavy guns mounted in a ship of given dimensions, or an increase in the dimensions of ships intended to carry a given number of guns.

In discussions of warship designs the relative merits are commonly assessed on the basis of what has been accomplished on particular dimensions and displacement. That method of comparison may be and often is carried to unreasonable lengths, no account being taken of the drawbacks and dangers involved in cramming many guns into ships. Freedom of action for each gun-crew, and a sense of security from interference arising from the fire of adjacent guns, are essential factors in the estimation of real fighting efficiency, even in days when the control of gun-fire from central stations is so much in vogue. Statistical statements may give to a ship so many guns and certain assumed arcs of command; but it is necessary to consider thoroughly what would happen if these guns were fired at their assumed extreme arcs of training before a true estimate can be formed of the efficiency of an armament. The limits of really safe training are often found in practise to be considerably less than the extremes embodied in published descriptions, and the results of firing trials cause narrower limits of training to be accepted. No good purpose is served when large arcs of command

exist only "on paper," and their utilization in action would involve serious risks to the structure, armament or personnel of the ships in which the guns are mounted.

## OBJECTIONS TO LARGE NUMBERS OF HEAVY GUNS.

One is led to inquire, in present circumstances, whether it is possible to discover a reasonable basis for fixing the maximum number of heavy guns which should be carried by a battleship. It has been previously stated that the number of heavy guns actually carried in ships built since 1905 varies from eight to thirteen per ship, ten or twelve being carried by most ships, and the stations varying from four to six. Although it is not possible to lay down hard and fast rules, or to reach any general agreement, certain considerations may be mentioned, which must be kept in view by all designers of warships. For instance, whenever heavy guns are mounted in positions near the middle of the length of a ship it is unavoidable that spaces shall be found for the installation of the magazines, shell rooms, ammunition supplies and gun-working machinery in a region mainly appropriated to the propelling apparatus and stowage of fuel. This juxtaposition of features essential to the efficiency of the principal armament and of those upon which efficiency of propulsion depend, involves considerable difficulties upon which one need not dwell. Experience on a large scale proves the need for special precautions in order that magazines may be kept cool and deterioration of the ammunition prevented; in not a few instances these magazine spaces make difficult the communications between compartments of the hold occupied by the propelling apparatus, or interfere with the efficient control and working thereof; while the arrangements for transporting coal from the bunkers to the stokeholds are rendered inferior in efficiency to those which exist in ships wherein the spaces assigned to engines, boilers, bunkers, are not broken up by magazines and shell rooms. It is also admitted that in ships which have five or six heavy-gun stations, the deck arrangements, the stowage and handling of boats and other matters incidental to every-day work and general convenience are all less satisfactory and convenient than are the corresponding features in ships where no heavy guns are mounted in the central portions of the length. In the last-mentioned vessels less difficulty is experienced in dealing with magazine temperatures, or in arranging for powerful secondary armaments, which shall be thoroughly efficient and practically free from risk of interference being caused by the fire of the heavy guns. It may be argued that these inconveniences and objections are relatively unimportant, that they have been and can be

overcome sufficiently for practical purposes, and that they must be accepted in order to obtain the essential quality of a preponderating offensive power. Even if this be granted, it still remains a matter for debate whether, on the whole, it is desirable to mount ten or twelve heavy guns in pairs and in five or six positions in any single ship.

The main reason advanced in favor of mounting ten to twelve guns in a battleship is that, in this manner, an overwhelming concentration of offensive power is secured. It has been the fashion in some quarters to adopt the simple method of assessing offensive power by counting the number of 12-inch guns carried. A ship carrying, say, twelve 12-inch guns has been reckoned equal to three ships each armed with four 12-inch guns even when the latter have carried in addition powerful and well-protected secondary armaments. It hardly seems necessary to deal with such a method of comparison in this paper and before this Society, and it will be more profitable to state certain governing conditions to which regard must be had in reaching a reasonable conclusion on the point now under consideration.

No one questions the importance attaching to a highly concentrated attack on an enemy: but it is equally certain that, in present circumstances—as naval actions will frequently be fought at long range—the fire of twelve 12-inch guns carried by three ships can be as effectively concentrated on any selected point in an enemy's formation as it can be when the guns are mounted in one ship. Again, three ships armed on the Michigan plan could concentrate the fire of twenty-four 12-inch guns as efficiently on a selected position in the enemy's formation as could be done by two ships of the Arkansas class with an equal number of guns. Indeed under certain conditions the three ships might have an advantage and be capable of keeping all their guns bearing on an enemy in rapid motion longer than could be done with all the guns in the two ships; because the provision of six stations instead of four in the latter necessarily introduces greater limitations of the effective arcs of command of some of the guns than are imposed on eight guns mounted as in the Michigan. This latter consideration no doubt has had much to do with recent advocacy of larger calibers than 12-inch for battleships, because it is realized that the multiplication of positions and guns in a single ship is accompanied by increased interference and possibly with diminished efficiency of fire control.

Multiplication in the number of gun positions has been necessarily accompanied by considerable increase in the length of battleships even when the protection and speeds have remained practically unchanged. As a contrast we may take the Arkansas with a length of 545 feet and twelve 12-inch

guns as compared with the Florida of 510 feet in length with ten 12-inch guns. It is true, of course, that increase of speed has even greater influence on dimensions and especially on length; but it is certainly remarkable to note the construction of armored ships which are about 700 feet in length and yet carry only eight heavy guns in four positions (13.5-inch caliber), whereas only five years ago ships about 200 feet shorter carried ten heavy guns (12-inch) in five positions, and others about 250 feet shorter carried twelve heavy guns (11-inch) in six positions. Such additions to length may not be considered objectionable on the ground of diminished maneuvering power, in view of the facts that in future long-range fighting will be the fashion, and that by various devices their handiness has been increased in proportion to their dimensions. On the other hand, it appears obvious that, when associated in fleets, vessels of this great length and high speed will require for safe handling an increase in the intervals between successive ships, so that the length of the line in proportion to the number of ships comprising it will have to be sensibly enlarged. Nor can it be disputed that this great increase in length renders greater the danger of damage from torpedo attack: the commander of a fleet composed of these long, swift ships may intend and attempt to keep outside torpedo range, yet in action that intention may not be realized.

Under-water attacks by torpedoes, by submarines and by mines are undoubtedly among the greatest dangers to which modern warships are exposed, although the gun still remains the supreme weapon of offense. It is agreed that a single successful blow struck by a modern torpedo will probably produce damage which will put even the largest ship "out of action" although she may remain afloat. On this ground, therefore, it may be maintained that a limit ought to be put upon the concentration of many heavy guns in single ships, and upon the increase in dimensions and costs of individual ships; because a single successful blow may, by general consent, bring about such a serious proportionate loss to a fleet by injury to one vessel and her compulsory withdrawal from action. Moreover, many services are required from a fleet in the performance of which capacity for distributing the force is no less important than the power of concentrating it for an attack. From this point of view unlimited increase in dimensions, cost and individual power of battleships is not desirable. As to the assertion that increased steadiness of ships, considered as gun platforms, necessarily proceeds *pari passu* with increased dimensions, it need only be said that experience has proved the doctrine to be fallacious. Battleships of the modern type carrying numerous heavy guns high above water, and protected by great weights of armor, must be endowed with considerable

initial stability in order to possess sufficient range of stability. As a consequence they have proportionately shorter periods of oscillation, as well as lessened steadiness under unfavorable conditions of sea. It is a matter of common knowledge also that some of the steadiest warships ever built have been vessels which were of small dimensions when judged by present standards. This feature in behavior, of course, is distinct from the power of maintaining speed in a sea-way; that quality is undoubtedly favored by increase in length and weight.

No claim is made that new statements of the case have been embodied in the foregoing summary of points in favor of or adverse to the adoption of battleship armaments comprising a large number of heavy guns in each vessel. All that has been attempted is to bring such points into view, fairly and briefly. Having done so the writer desires to place on record his personal opinion that in no case is it desirable to carry more than eight heavy guns in a single ship, that these guns are best arranged in four positions as in the Michigan class, and that they should be supplemented by a powerful and well protected secondary armament.

## INCREASE IN CALIBER OF NAVAL GUNS.

Allusion has been made to the movement now in progress for using guns of larger caliber in battleships and armored cruisers. In the United States the 14-inch gun has found favor; in Great Britain the 13.5-inch has been reintroduced; in Germany the 12-inch has been adopted instead of 11-inch, and an experimental 13.5-inch gun has been made and tested. The reasons given for this departure from long-established usage may be summarized as follows:—

1. With larger calibers it becomes possible to reduce muzzle velocity and to diminish erosion in the interior of guns, and yet to secure ample penetrating power against armor and superior maintenance of energy at long ranges.

2. A flatter trajectory and increased accuracy at long ranges can be obtained with guns of larger caliber.

3. Increased capacity of bursting charges can also be secured for all descriptions of shells.

4. If it be assumed that a certain total striking energy and a certain total shell-burster effect are to be obtained by one discharge of all the heavy guns mounted in a ship, then it is possible to diminish the number of guns carried if the calibers are increased, and to obtain more efficient control of fire.

All these arguments in favor of larger guns are, in principle, identical

with those employed more than thirty years ago when increase in the weights and calibers of naval guns was made with great rapidity. The arguments then prevailed for a time; and history is, in this particular, now repeating itself. At that period in the British Navy we passed from 12-inch breech-loading guns weighing 45 tons and firing projectiles of 714 pounds, to 13.5-inch guns weighing 67 tons and firing 1,250 pound projectiles, ending with guns of 16.25 inches caliber weighing 110 tons and firing 1,800 pound projectiles. Within a few years experience then induced a return to 12-inch guns and for a long period no larger caliber was used, but great and continuous improvements were made in guns, projectiles and explosives. Behind the reversion to more moderate calibers stood the conviction, based on actual usage and experiment, that the 12-inch caliber was sufficiently large for all practical purposes, whether armor-perforation or shell-power was considered; and that, on the whole, for a given expenditure of weight on the principal gun armament of a battleship the 12-inch gun furnished the best combination of adequate numbers and individual power. It has been stated recently that the chief reasons for abandoning the larger calibers were to be found in the difficulty encountered in making such guns or in loading and working them. As one who was intimately concerned with the matter the writer denies that these were the real causes of return to the 12-inch caliber. The subject was fully discussed by the Admiralty in 1888, when the designs for battleships of the Royal Sovereign class were under consideration, and it was then decided to make the change as soon as possible; but no satisfactory design for 12-inch guns was then available and consequently the 13.5-inch caliber was used once more. At the same time action was taken to obtain a new and satisfactory design of 12-inch gun, and as soon as it was available it was adopted in the Majestic class (1892).

Twelve-inch guns of the latest design are much more powerful weapons than their predecessors of twenty years ago; their projectiles are capable of penetrating at very long ranges the thickest hull armor fitted on the sides of existing battleships. As regards armor perforation, it is generally admitted that no increase in caliber is required. Although their trajectories may not be so flat as those of larger guns, practise made at sea with 12-inch guns at very long ranges is undoubtedly excellent. For the same approximate total weights of guns, ammunition, gun-mountings and mechanisms, and protecting armor it is possible to provide for five pairs of 12-inch guns as against four pairs of 13.5-inch guns. In other words, if equal rapidity of fire is assumed to be obtained by guns of the two calibers, for each ten rounds delivered by the 12-inch guns only eight rounds would be delivered from the 13.5-inch. It is improbable that in actual service equal rapidity

of fire would be long maintained by the larger guns; but in any case the unavoidable uncertainties attaching to naval gunnery make the larger number of rounds fired and of hits made by the 12-inch guns a most important feature in the comparison of their efficiency with that of larger guns. For attack on the armored portions of modern battleships (as already remarked), blows from the 12-inch guns are admittedly heavy enough so that they would have a distinct advantage in this respect. In regard to shell fire, trials made against the French battleship Jena and against several British ironclads demonstrate conclusively that shell fire from 12-inch guns can rapidly destroy unarmored portions of battleships and can inflict great damage on the armored portions and on protective decks, provided projectiles of suitable design are used. The larger bursters possible with 13.5-inch shell—say about 40 per cent. greater in weight than the bursters of 12-inch shells—will undoubtedly inflict greater damage for each successful hit; but the number of such hits will be smaller unless the weight assigned to the principal armament and its protection is increased so as to have an equal number of the larger caliber guns; and that means the construction of larger and more costly ships. Fancy pictures have been drawn of wholesale damage which can be done by the explosion on board a warship of one common shell from a 13.5-inch gun, and of its far-reaching and destructive effects as compared with those of a single shell from the 12-inch gun. The writer has witnessed many experiments with high explosives, and knows that enormous local injuries may be inflicted by a single shell explosion. Yet he ventures to doubt the accuracy of much that has been written both as to the vastly greater relative power of 13.5-inch shells and as to the absolute necessity for adopting guns of that caliber in order to secure effective shell fire. Without assuming the rôle of a prophet, he is of opinion that just as history is now repeating itself in regard to the adoption of larger calibers, so in the course of a few years it is likely to repeat itself by a return to more moderate calibers as experience is gained and extended firing trials are made with the larger guns now being introduced. All the reasons given above for preferring the 13.5-inch caliber to the 12-inch would apply also to an argument in favor of still larger guns; and it may happen that, before the tide turns, larger calibers than 14-inch will be again mounted just as was done thirty years ago. But the turn will doubtless come in due course and for the same reasons as before.

### TORPEDO ARMAMENTS OF BATTLESHIPS.

In conclusion brief reference may be made to the questions of equipping modern battleships with an armament of locomotive torpedoes. There

was a time when the multiplication of above-water torpedo-discharging stations found great favor and when advocates of that system thought its advantages great enough to compensate for cutting through thick armor in order to provide apertures for the passage of torpedo tubes or for accepting considerable and unavoidable risks incidental to the exposure to an enemy's fire of many torpedoes with large explosive charges without any armor protection. For a long time past and by common consent the only form of torpedo-discharge stations which has been considered appropriate for use in battleships and large armored cruisers has been from submerged positions; and even these well-protected positions have not always been occupied, because naval opinion has been, in some cases, against the use of locomotive torpedoes in vessels of these classes. Present practise is really based upon the consideration that although the torpedo armament of a battleship can only be of use occasionally and probably at long intervals, the fact that its installation makes relatively small demands upon space, weight and cost justifies the introduction of a limited number of submerged torpedo-discharge stations; so that when, if ever, occasions for making use of that form of attack should occur the means shall be available for making it effectively.

Among those who accept the prevalent view that it is desirable on the whole to install under-water torpedo-ejecting stations in modern battleships opinions are divided as to the best and most important positions from which torpedoes can be ejected. Some advocate only broadside ejection, others add bow tubes and stern tubes. Some favor fixed tubes, others consider training tubes to be preferable. On this occasion no detailed discussion of these points is possible, but in the opinion of the writer it seems preferable on the whole to adopt fixed broadside tubes only and to place them in suitable positions. Special dangers are obviously incurred in connection with under-water bow tubes and there seems good ground for questioning the desirability of fitting stern tubes, because their use involves the necessity for carrying large explosive charges in the immediate neighborhood of steering apparatus and propellers. Moreover, it is difficult to conceive circumstances under which battleships would be likely to require or be advantaged by possession of stern tubes when acting in company with other ships in a fleet.

On the other hand, it is true that the sizes, speeds, accuracy and effective range of locomotive torpedoes have been considerably increased in recent years and the effective range of torpedo attacks, which was formerly 800 to 1,000 yards, has been increased to 2,000 or 3,000 yards. Enthusiasts in torpedo warfare, indeed, look forward to effective ranges from 6,000 to

8,000 yards soon becoming possible, although that is probably an extreme view not likely to be realized. This development of torpedoes has been held in some quarters to imperil the supremacy of guns in naval warfare. Designs have been prepared for armored torpedo vessels which should possess high speed to carry a great number of torpedo ejecting tubes and be practically gunless. Other persons have advocated and designed in outline types of vessels in which a large number of torpedo stations were associated with special types of guns intended to act chiefly as howitzers and to fire shell containing large bursters of high explosives. These speculative designs need not be seriously considered. The gun still remains and will remain the supreme weapon of offense. Its greater accuracy, especially at long ranges, its much greater rapidity of fire and the possibility of efficiently mounting in a single ship a considerable number of guns all tell in its favor as they have done throughout the period since artillery was first introduced into warships.

NOTE:—This last paragraph was contained in the original manuscript, but was omitted inadvertently from the preliminary copies issued for discussion, time not permitting proof reading before distribution.

THE SECRETARY.

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## DISCUSSION.

THE PRESIDENT:—You must have noted with pleasure the inferential compliment paid to our own naval constructors by Sir William, that it was a new and bold departure in the Michigan and South Carolina to place two turrets in each of the supreme positions, and to arrange for firing the guns in one turret over the top of the other turret. This paper is now before you for discussion, and I wish to say that the discussion is not to be limited to the actual membership. Any gentleman on the floor will be very gladly heard in these discussions. I first ask the Secretary to read the written discussion.

THE SECRETARY:—The Secretary would state that owing to certain unfortunate circumstances existing in New York recently, the papers have had to be handled by mail, causing delay in distribution. He will now read a memorandum from Admiral Mahan on this paper.

REAR ADMIRAL A. T. MAHAN, U. S. A. (Communicated)—My comment upon the paper, which I have read carefully, must be confined to a brief expression of my general agreement with the conclusions of Sir William White (page 16) and the following summary of the leading principles I conceive to be involved in the controversy between the all-big-gun ship, which, barring torpedo defense, is to carry no armament except a few of the very heaviest caliber used by its nation,

and the mixed battery vessel, which, to fewer of the heaviest guns, adds a proportioned number of comparatively light pieces variously called secondary or intermediate. This is the type which commands the adhesion of Sir William White.

The argument for the all-big-gun ship, briefly, is that it and the squadron to which it belongs will always be able to keep at its own desired range; and that, being so able, it can and will always choose such a distance that the smaller guns of its opponents will be practically "out of action," an aim which Sir William White accurately quotes as that of all-ship fighting. Under this condition, the circumstances of the two fleets are reduced to the most heavy guns of the all-big-gun fleet opposed to the fewer of the mixed-battery fleet.

The reply to this is, that the fleet speed of any body of vessels is the speed of the slowest among them; and the maintenance of the all-big-gun distance presupposes a perpetual avoidance of close action by the fleet depending upon it, that is, constant withdrawal; that any mishap lessening the speed of a single member of the fleet entails the abandonment of that member or the acceptance of close action, within the range of the mixed battery. The pursuing fleet follows with its best speed, because its slower members are in no danger, and will come up as a reserve.

Much stronger assertion is made as to the inferior accuracy of the smaller caliber, under conditions of modern action. Sir William White tells us (page 5) that naval officers having full and accurate information on this subject have assured him that the percentage of hits obtained with 6-inch guns under service conditions is not inferior to percentages obtained with guns of larger caliber. Accepting this, and also that, as was the case with battleships but a few years ago, three 6-inch are carried for one 12-inch gun, the number of 6-inch hits "under service conditions" would be to 12-inch as three to one. This is "volume of fire." Considering the large amount of surface penetrable, and of crew accessible to 6-inch projectiles, it is a very material consideration. It is to be remembered that the 6-inch projectile weighs 100 pounds, and that the repeated near burstings of such in rapid succession, even where they do not penetrate, is a tremendous nervous strain upon men subjected to them. This the Russians experienced at Tsushima.

The very striking success of the system of fire control developed within the past few years has led those to whom the credit of this belongs to insist much upon the difficulty of observation of the fall of projectiles, where two calibers are used. The splash of the 12-inch and of the 6-inch are often indistinguishable. I think this argument presupposes a deliberateness of fire control which will not obtain after the action becomes "hot." Till then, like two fencers measuring each other's strength, there may be "passes" with the 12-inch on each side to ascertain distance, and this will and should continue as long as possible. How long, is the question.

The all-big-gun conception leads necessarily to the wish for as many such guns as possible; or, what in aggregate impact is much the same, to each gun being

made of as large caliber as possible. We have now risen from four big guns to twelve or thirteen, and from 12-inch to 14-inch. The notorious difficulty of placing several pairs, shown by Sir William White, necessarily of itself impels to fewer pairs of heavier guns. This means of course proportionately fewer discharges and fewer hits. All is staked on the disastrous effect of the large projectile, hitting less often; just as against a mixed battery all is staked on the secondary (or intermediate) battery—the 6-inch guns—being kept out of action by superior speed.

The assumptions of the advocates of all-big-gun ships are precarious though plausible. Chief among them is the assured ability to choose distance, at least for a time, long enough to cripple the assailant decisively. This is the cornerstone of the whole edifice. Upon this is built up the entire program—more and more big-gun fire, therefore bigger guns with fewer emplacements; bigger and bigger ships and fewer of them. Sight is lost of the fact, which Sir William brings forward, that the guns in three ships can be brought to bear effectively on the same number in two ships. This is concentration of fire; while the three ships, as compared with the two, give dispersion of target, a defensive provision entailing little offensive loss. This is exactly as in harbor defense; guns bearing from numerous positions on a critical point concentrate fire, yet gain comparative immunity through their separateness—dispersion of target.

The efficacy of bigger ships and fewer of them depends in part upon the considerations of concentration of fire—upon a few ships, and upon dispersion of target—among several ships, or gun emplacements. A bigger ship has an evident advantage over a smaller in a ship duel. In a fleet action the bigger ship reinforces proportionately the position in the fleet in which she is placed. But it does not follow that, in a combat of two ships against three, or eight against twelve, the same inequality continues. The dispersion of the target among twelve ships, the localization of a severe injury in one smaller ship instead of one bigger, the larger power of combination in twelve units over that in eight, all tend not only to compensate but to overcome the concentrated power (not concentrated fire) of the larger vessel, which is conspicuous in a ship duel.

The question ultimately is the difficult one of drawing a line. No one, for instance, wants one-gun ships, but a respectable school revolts at the twelve all-big guns; and the revolt is greater when more are proposed with increasing size of vessel and reduced numbers in the fleet. Collateral questions arise, *e. g.*, dockage for such vessels and their use of navigable waters. Already Chesapeake Bay is found too shoal for the increased draughts of battleships.

In conclusion Sir William White mentions that the Japanese have not abandoned the secondary or intermediate battery. I believe that this is also true of the German Navy, if not indeed of all save the British.

PROFESSOR WILLIAM HOVGAARD, *Member:*—This paper puts the question of the armament of battleships before us in a remarkably clear way; it disentangles in an

analytical manner the different factors which influence the problem, and makes it relatively easy to evaluate them and to assign to each of them their proper weight.

1. *Disposition of Guns.*—I fully agree with Sir William White, that when the end positions are utilized by placing two turrets at each end of the ship, mounted as in the Michigan, any further addition to the number of gun turrets is undesirable since it can only be made by sacrificing to some extent the arc of fire of such additional guns, and by incurring interference. The Michigan arrangement seems indeed the ideal.

On the other hand it appears to me that if it is possible to design, or rather to develop, an efficient triple turret, this installation should be adopted. We shall thereby be able to mount twelve guns in one ship, all of which shall have the maximum arc of fire. At the same time all the advantages inherent in the Michigan arrangement will be retained, viz., favorable conditions for storage of ammunition, freedom from gun interference and facility of mounting a powerful secondary battery. The relative risk by thus concentrating three guns in each turret will not be greater than incurred by the twin turrets in the Michigan, since in both cases 25 per cent. of the primary battery will be put out of action by the disablement of one turret, and the target presented by four triple turrets is smaller than that presented by six twin turrets.

The tactical concentration obtained by mounting, for instance, twenty-four guns in two ships instead of in three ships seems to me an undoubted advantage.

2. *Anti-torpedo-boat Battery.*—If, in addition to the 6-inch guns proposed by the author, a battery of lighter "man-killing" guns is to be carried, it appears to me best to place them on disappearing mountings, such as those designed by the Creusot firm in France, where these guns are lowered when not in use, so as to be sheltered by the side armor. The number of such guns must then be reduced, but it seems better to possess a smaller number of protected guns than a greater number of guns which are almost certain to be demolished in ship or fleet actions.

3. *Caliber of Guns.*—Even it if be granted that the technical difficulties which stand in the way of increasing the caliber may be solved satisfactorily, so that these heavier guns may be worked as quickly as the present 12-inch guns and so that they may have as long a life, it still remains to be proved, as pointed out by Sir William, that equally good or even better results cannot be obtained with 12-inch guns.

The heavy guns are to my mind essentially armor piercers, and armor piercing can only be done by heavy guns. The larger guns now being introduced are, however, to be superior to the present 12-inch guns, chiefly in their greater shell effect, it being generally admitted that the armor-piercing effect of the 12-inch guns is adequate. Now shell effect cannot generally be expected to affect the vitals of a ship directly; its action is based on a demolition of unarmored or lightly armored parts, and is essentially external. This work is indeed very important, but may perhaps better be carried out by a greater number of 12-inch guns which give a more widespread fire than by the concentrated effect of a smaller number of heavy guns.

The armor-piercing effect has much greater chances of reaching the vitals, of dealing deadly blows, and a greater number of 12-inch hits seems here preferable to a smaller number of, say, 14-inch hits, the individual effect of which is not much greater.

It must be borne in mind, also, that with a given number and disposition of guns, an increase in caliber means an increase in displacement, and this leads up to the main point which I want to discuss, viz., whether such addition to the displacement and hence to the load carried is not much better employed in strengthening the torpedo armament and the protection against submarine attack.

4. *An Increase in the Torpedo Armament of Battleships and in their Submarine Protection.*—It will probably be objected by many, that it is of no use to fit a powerful torpedo battery in battleships, since future battles will be fought on great ranges. The torpedo is in other words regarded merely as a defensive weapon which, so it is thought, forces the ships to keep on long ranges. This doctrine of long-range fighting, which has become so generally accepted during the peace period following the Japanese war, is not supported in a definite manner by the experiences of that war; it certainly breaks down in thick weather and under many circumstances due to navigational difficulties. But also from a purely tactical point of view, the doctrine seems open to serious criticism. History furnishes an abundance of examples where similar theories have been exploded, both on land and sea.

Before the time of Frederick the Great it was considered the highest art of strategy and tactics to try to secure secondary advantages by the occupation of outlying fortresses or territories of the enemy, by securing strategical bases and by overwhelming and defeating minor detached forces, while decisive action against the main army of the enemy was avoided. Frederick the Great broke entirely with this custom; he went right for the enemy's main army, fought it and destroyed it. He was severely criticised for this unscientific method by contemporary strategists, but he always beat his enemies. Precisely the same strategy and tactics were followed by Napoleon, no maneuvering about the enemy at great distance, but decisive blows at close quarters was his principle.

Nelson had the same principle. Before his time fleets would keep going at great ranges, sailing along parallel lines, firing for whole days at each other without much result, but Nelson broke completely away from these tactics. Thus at Aboukir, at Copenhagen and at Trafalgar he engaged the enemy at close quarters.

I do not mean to intimate that ships will fight at so close ranges in future battles as was the case at the time of Nelson, but it seems to me quite possible that commanders may by found who will prefer fighting at ranges of a few thousand yards, and who will use their superiority in speed, if any, in trying to close in with the enemy instead of running out to maximum range.

This seems the more likely to occur if we equip the battleships as I propose, by giving them, on the one hand, a powerful torpedo battery, and on the other a stronger underwater protection.

As I have shown elsewhere (Jane's Fighting Ships, 1910) that it is quite

possible, on a displacement which is not now considered excessive, to endow a ship with a powerful armament of 12-inch guns, a battery of some twenty-four submerged torpedo tubes and a 4-inch underwater armor, placed externally on the bottom of the ship; the speed to be at least one knot more than the ordinary battleship speed. A battleship of same size of the type now in vogue, armed with a number of, say, 14-inch guns, but with only four to five torpedo tubes and with a relatively weak bottom, will stand very little chance of surviving an action at close range with a ship of the above proposed type.

I believe that the attention has been fixed too much on the artillery. In the struggle for the attainment of supremacy in this respect, it appears that the torpedo has been forgotten or put in the background.

The development has become one-sided and the result has been inharmonious designs, for while the modern Dreadnoughts are extremely powerful in some respects they are very weak in others.

Quite apart from the question of torpedo armament, it has become a necessity to give the battleships a much better protection against submarine attack than is at present the case. This is due to the fact that the torpedo itself as well as the vessels which carry torpedoes as primary armaments, and notably submarine boats, have recently developed to the point where the risks of destruction now encountered by battleships due to submarine attack are at least as great as those due to attack by artillery. We should, however, never increase the weight given to the defensive in a battleship, without at the same time increasing the weight given to the offensive, and a more powerful torpedo armament is the natural correlation of an increase in underwater protection. (Applause.)

Naval Constructor David W. Taylor, U. S. N., *Vice-President* (Communicated):—The Society is to be congratulated that the distinguished author of this paper should have enriched its proceedings with a contribution on a subject of vital interest to so many of our members and based upon professional experience unsurpassed by any naval architect to-day. If there are those among us who materially disagree with him on some points, they should be prepared to bring forward substantial facts and figures to sustain their position.

It seems to me, however, that the majority of the conclusions of the author will be accepted by those who have given much consideration to the subject matter.

Certainly, as regards the disposition of heavy guns recommended, it cannot but be pleasing to the distinguished member of our Society who was responsible for the bold departure taken upon the Michigan and South Carolina to find the author not only endorsing it, but pointing out the fact that it has been largely copied in other navies. "Imitation is the sincerest form of flattery." I would like to point out, however, in this connection, that the "vertical echelon" disposition of turrets upon the Michigan and South Carolina was not adopted until careful and thorough experiment had shown its entire feasibility. The great question was whether it would be possible to fire the two guns of the upper turret immediately over the

lower turret. To determine this question, a 12-inch gun was mounted on the monitor Florida (now Tallahassee) so as to fire over the turret, and firing trials carried out, there being imprisoned in the turret, I believe, first cats and dogs, then midshipmen and so on up to rear-admirals. After the question of safety was settled, there were, of course, a number of other questions of prime importance, such as the provision of adequate strength in the supports of the upper turret, the sighting arrangements for the lower turret, etc. The results of target practise of the four vessels of the fleet now in service with the "vertical echelon" arrangement of turret have been, I may say, very good, indicating that the many problems of the constructor and ordnance engineer involved by the new departure were successfully solved.

The distinguished author believes in the four-turret diposition of the Michigan, as against five and six turrets, as found on later ships. This opinion is shared by many of the most capable and experienced officers in the United States service; but it is not possible to install the number of heavy guns demanded by the majority of our officers in four-gun positions unless we use three-gun turrets.

The author is not in favor of the triple-gun turret, although he does not take strong ground against it. He says, in effect, that only war experience could finally settle the question of its desirability. On this point I would like to mildly disagree with the author, and record my opinion that war experience may be most deceiving. If we could have a war lasting several years with a battle every month, the experience gained would of course be conclusive as regards practically all professional questions. But when there is but a single battle, or two at most, the elements of chance may very well entirely obscure the result as regards technical matters. We naturally draw as many conclusions as possible from the practical experience of war; but, I repeat, results of a single battle may well lead us to fallacious conclusions.

At the battle of Lissa, in 1870, the victors used ramming tactics most successfully, and, for years, every navy in the world attached great importance to the ram. When we undertook the reconstruction of the Navy, about 1881, a number of rams were recommended by the First Advisory Board, and finally we built one upon the ideas of a most distinguished officer, completing it more than twenty years after the battle of Lissa.

By that time, however, the development of the gun and torpedo had practically wiped out the chances of successful ramming, and the experience of the battle of Lissa is not now regarded as warranting any importance being attached to the ram as a naval weapon.

It is very doubtful if it really warranted the importance attached to the ram during the few years immediately subsequent to the battle.

There is a good old English proverb, which, it seems to me, should always be borne in mind when we undertake to learn the "lessons" from a naval battle, namely, "One swallow does not make a summer."

In his advocacy of good secondary armaments, the author takes strong ground on one side of a much debated question, and produces strong arguments for his contention.

There is no question that to-day the disposition and protection of the secondary armament of a large battleship is about the most puzzling problem of the whole design, and happy the designer who has no secondary armament to contend with. In the Michigan and South Carolina we had practically no secondary armament, because on the limits of displacement it was not possible to provide it, but we soon reverted to it.

Most nations have never given it up. England alone has practically left off a secondary armament from a number of ships. It is true that we call our secondary armament "anti-torpedo-boat guns" or some such name, but the fact remains that it is a powerful battery, the 5-inch guns we now fit being about as powerful as the 6-inch guns of a few years ago.

If we may judge the future by the past, the secondary armament will refuse to stay abandoned in any navy.

The English Dreadnought of nearly thirty years ago—the largest, fastest, most powerful vessel of her time, outclassing all others, had practically no secondary battery. About that time, the torpedo-boat menace grew, and the secondary battery began its rise. It was given a big impetus about 1884 by the destruction French quick-firing guns wrought in an affair with the Chinese, and the secondary battery grew and grew until, a few years ago, it grew up to the primary battery. Immediately, however, the development of a new secondary battery began. There is little doubt that, whether logical or not, the secondary battery will persist in spite of the difficulties connected with it, and the author's belief in 6-inch guns seems fully warranted by the almost universal practise of the present day. Indeed it seems very probable that even England will soon fall into line in this respect.

The statement on page 10 that "in many cases history has been repeating itself" appeals particularly to me. No one can study naval developments for even a few years back without finding many cases where naval opinion has swung around in a circle, and the author, with his experience of forty-three years, is doubtless able to recall a number of cases where the complete circle has been traversed more than once. While many naval officers are conservative, there is no question that naval opinion as a whole, if reflected, as presumably it is, in designs of naval vessels—has during the last fifty years been in a constant process of change and re-crystallization in marked contrast to the conditions during the early part of the last century, and for at least two centuries before.

It may be interesting to recall that this period of shifting opinion is practically coincident with the development of the naval architect and marine engineer as paramount factors in the design of naval vessels, and it might be maintained that the technical man is responsible for the incessant change in naval opinion, and not the traditionally conservative seagoing officer. (Applause.)

CHIEF CONSTRUCTOR WASHINGTON L. CAPPS, *Vice-President:*—It is to be regretted, I think, that officers of the Ordnance Branch of the naval service are not here to participate in the discussion, as it deals with matters that particularly

affect that portion of the service. It is also to be regretted that those of us who perhaps could speak with some authority on the matters treated are, for obvious reasons, somewhat restricted in the expression of our views. Some years ago authoritative knowledge concerning naval development was much more freely disseminated. That period of ready access to official plans and documents has been followed by one of comparative secrecy. I say comparative, because no matter how seriously it may be attempted to keep such data secret, those interested in such matters usually find out much concerning them, and oftentimes we only succeed in concealing information from our own people, who would doubtless profit by the knowledge, while those we desire particularly to conceal it from have more or less complete information.

Sir William has very modestly stated that "no claim is made that new statements of the case have been embodied in the foregoing summary of points in favor of or adverse to the adoption of battleship armaments comprising a large number of heavy guns in each vessel. All that has been attempted is to bring such points into view, fairly and briefly."

I think Sir William is to be congratulated on the very fair and impartial exposition of the case. He arrives at certain definite conclusions, and gives the reasons for those conclusions, and I think his paper is one that can be read with the greatest pleasure, and with very little, if any, adverse criticism.

The subject of warship design is one that is necessarily subject to many varying opinions, and sometimes the opinion of the same individual is by no means the same to-day that it was last year. The most we can hope for is that those charged with the responsibility of warship design shall give to this most important matter their very best energies, and that those who have anything to do with the operation of the completed ship should give, to those who have the immediate responsibility for design, the benefit of their experience in every way possible. By such means the results attained will be the best possible.

Sir William has made most appreciative allusion to the work done by the United States Navy in recent battleship development. Of course, whether or not he is justified in his tribute must be left to others. I think, however, that all of you, not only as members of this Society, but as citizens of this country, are especially interested in knowing with what care we have adopted certain principles of warship armament, and it is gratifying to realize that our conclusions have now been very largely accepted by our colleagues in other countries.

Sir William has stated in effect, and I believe he is correct in the statement—that the South Carolina and Michigan are the first battleships of this most recent period of battleship development which have the middle line arrangement for all the heavy guns, and are the very first to have that special form of emplacement of turret which permits No. 2 turret to fire over No. 1, and No. 3 to fire over No. 4. This method of gun emplacement was not arrived at in any haphazard way; it was a matter of considerable experiment. The time of making these experiments is now long past, and so much publicity has been given to some of the details that I

am sure I shall violate no confidence in giving you a brief indication of a few of the steps taken by the Navy Department before accepting and adopting that form of turret-mounting. It had been contended by many that this system of mounting was entirely impracticable, and would prove so in service; that, while the materiel might stand the blast of the upper turret guns, the personnel in the lower turret could not. Many experiments were made, first with turret structures on shore, and subsequently by so mounting a gun on board ship as exactly to simulate the conditions which would exist on board ship in the proposed design. We began the experiments with only animals in the lower turret which was being fired over and measured the intensity of the blast by pressure gauges; subsequently, the best possibly practical test was made by stationing in the turret in the places of maximum pressure the officers who were really responsible for the design. (Laughter.) Those gentlemen had witnessed all the experiments, of course, but from a comparatively safe distance, as did all the others engaged in making the experiments; but, on this occasion, they had such great confidence in the design that they themselves went into the lower turret and were promptly followed by others; they were then in an excellent position to say that it was an entirely practicable arrangement and that the guns of the upper turret could be fired under the most disadvantageous conditions, and with entire safety to the men in the lower turrets. That, in brief, is the procedure that the Navy Department adopted before accepting that method of mounting for the turret guns of its first battleships of this type.

It is also gratifying to note that the development along that line has been quite continuous, and although our later ships have increased in size and in the total number of heavy guns, the method of mounting originally demonstrated by experiment has been continued; and other very important naval powers have also come to accept this method of mounting as being one of the best.

I almost feel like apologizing for making this reference to recent U. S. naval designs, because it concerns matters in which I have had some considerable personal interest; but now and then one reads very adverse comment concerning our naval materiel, and it is therefore somewhat reassuring to know that our naval progress is being watched with interest by foreign navies and that certain very important features of our designs are being incorporated in those of leading naval powers.

I could not attempt to go over the many interesting points raised by Sir William. This kind of paper is one which should bring forth a most useful discussion from a great many interested sources, and I sincerely trust, for the information of those responsible for our warship designs—for the information of all of us, in fact—that the written discussions of this paper will be very complete, as it will unquestionably add greatly to the value of our proceedings.

Before concluding these brief remarks, I desire to invite attention to a comment made by Sir William which struck me as exceedingly interesting. It is one that has been discussed before, of course, but one to which I do not think sufficient attention has been paid. We all know the marvelous advances made in gunnery

practise during the last few years. To those who do not have access to official records, this progress is almost phenomenal. It is only a few years ago that 2,000 yards was accepted as a very reasonable battle range. Recent battle practises indicate that this range may be increased to 7,000 or 8,000, and even to 10,000 yards and more. There is one important condition, however, that is often overlooked in assuming that actions will take place at such long ranges, and that is a condition which no one can control, and the controlling effects of which are very likely to be experienced in actual battle; I refer to the atmospheric conditions. In one very important body of water in northern Europe, it is a rule rather than the exception that you cannot see clearly 2,000 yards away. It frequently happens on our own coasts that the atmosphere is so hazy that you cannot see accurately 5,000 yards away. These atmospheric conditions must have a very important bearing on the range at which battles can be fought. Anyone, therefore, who assumes that an arrangement of armament which provides for a very long battle range is necessarily the best one because we will have long battle ranges, leaves out of account the important consideration of atmospheric conditions. Moreover, while we have made very great strides in naval materiel, and while I have great faith in the efficiency of the later developments of big gun ships, I am not one of those who consider that all preceding designs of another type are worthless. In fact, in my judgment, such a conclusion is very far from the truth. In the final test of battle, both as regards ships in the main line and in reserve, the ships which immediately preceded the all-big-gun ships will give a very good account of themselves. So I do not think we will be justified in dismissing that portion of our Navy as being obsolete and without value.

Personally I feel very much indebted to Sir William White for presenting his views on so important a subject in so concise and impartial a manner, and I greatly regret that the limitations imposed upon us prevent any very detailed discussion of the paper, by the presentation of facts deduced from our own professional experience. (Applause.)

Naval Constructor Joseph H. Linnard, U. S. N., *Member*:—Mr. President, most of the points I had thought to make comment upon have already been touched upon by the previous speaker, but it may be said that the paper is largely a protest against the present tendency in battleship designs. I think we all have to admit that there are fashions in ships as well as in other things, and those who protest against the fashions are apt to find that their arguments, however well considered, fall frequently upon deaf ears. Fashion, although sometimes based in part upon reasoning, is also largely based upon caprice. Now fashion in warships at the present time indicates larger displacements. No nation is willing to take a battleship that displaces less than the contemporary battleship of other nations. Nor is it willing to have a battleship of less speed, nor is it willing to have a battleship that has apparently less guns on it. The point which seems to draw least attention in the modern fashion is the question of protection, of which Professor Hovgaard

has fully spoken. Yet to some of us that very question of protection seems to be the one toward which, if we are to have a fashion, the fashion should be directed.

The tenor of Sir William's argument is the limitation of the number of guns devoted to a single ship, and this naturally falls in with the point of view of those who believe in greater protection. If we agree that displacements cannot be reduced, we can put our capital represented by displacement into armament, protection or speed; and, as Professor Hovgaard very justly remarked, it seems to many of us that we have not balanced in our modern ships the parts devoted to each of these features. If, then, we limit the amount devoted to armament by reducing the number of guns, or by limiting their size, we can devote more displacement to protection.

In the spring meeting of the British Institution of Naval Architects a paper was read in which the writer indicated his belief that the tendency would be to reduce protection and to increase very greatly speed, and perhaps armament, and this may be the tendency of fashion; but if the views that have been so strongly presented here this morning carry weight, the eventual result will be to ward increasing protection rather than increasing armament.

The disposition of guns upon the center line exclusively has been touched upon by previous speakers, but the alternative arrangement, by which at least a pair of turrets are placed upon the sides of the vessel, has been strongly advocated by many on the ground of increased end-on fire, which some consider extremely necessary. Even if one grant the desirability of increased end-on fire, it has never appeared to me that the arrangement of side turrets accomplishes the results desired. If we take the fire directly forward, as exemplified in the South Carolina-Michigan design, we are able to fire without danger, as has been explained by Admiral Capps, four guns directly ahead. Nominally, we are able to fire six guns directly ahead, with three turrets arranged, one in the center line, and two on the sides; but I believe I will be sustained by officers who have managed battleship turrets and gun-fires, that this is not a practical proposition. In other words, a ship cannot be steered exactly at an object—the target or the enemy—and will, even if it is approaching directly, sheer off to one side or another in its progress. Now it takes but a very small angle in any of these arrangements with side turrets to blank one turret or the other, so that for all practical purposes the center turret and the turret on one side or the other are the ones that are fired, but not both of the side turrets in the circumstances in which ships are steered at sea; and even if we can fire the three turrets directly forward or aft, it is obvious, in an attack at least, that position cannot continue any length of time without bringing the two enemies—the ships opposing—in contact, and hence can but momentarily exist.

The question of secondary batteries is somewhat complicated by the progress in size and weight of guns of nominally the same caliber, and it may be said that the latest 5-inch guns we are using on our ships have practically the same weight as the 6-inch guns of an earlier date; so that the 5-inch guns we have mounted may be practically described as 6-inch guns with a 5-inch hole in them, and if we consider

such guns mounted in positions in which they can be used in action against other ships, it seems sufficiently obvious that no commanding officer will refuse to use such guns in an action because they are denominated anti-torpedo guns; if he is able to fire them he will use them against an enemy. If such is the case, it seems the part of wisdom to make such guns of at least such a caliber and weight that they will be effective guns against the enemy's large ships. (Applause.)

SIR WILLIAM WHITE (Communicated):—Having carefully read the notes of the discussion which followed upon my paper when it was read I would submit the following comments.

To all who joined in that discussion, either in speech or writing, I would desire at the outset to express my thanks for the kind terms in which reference has been made to the value of the paper and its fairness of statement of the case. It is also most welcome to me to find such a consensus of opinion in favor of the main conclusions at which I have arrived among gentlemen of recognized authority on the subjects treated.

Although I have necessarily bestowed much time and thought on the study of naval strategy and tactics in connection with the design of warships, it seemed best to minimize my references to that branch of the subject in the paper, and to dwell chiefly upon those features of the problem which directly affect the designs of battleships. The fundamental idea which I had in view, however, and on which my criticisms of single-caliber big-gun armaments were chiefly based, is exactly that which Admiral Mahan has expressed admirably and tersely when dealing with the question of the possibility of maintaining a very long range in action. Admiral Mahan is absolutely correct in the statement that maintenance of long range by a fleet or ship possessing superior speed is only possible by means of "constant withdrawal," and a possible abandonment of any ships in that fleet which may be temporarily hampered in their steaming capability, or be compelled to slow down in consequence of injuries. Moreover it is a matter of common experience in maneuvers in the Atlantic, and particularly in northern seas (where fogs and thick weather frequently prevail), that fleets accidentally blunder against another and make the discovery suddenly that they are in close propinquity. For these and other reasons I am convinced that the possession of a powerful and well-protected secondary armament of 6-inch quick-firing guns should be an essential feature in the armament of modern battleships. As Admiral Mahan points out it is most unwise to state everything on hypotheses which may not or cannot be fulfilled in practise, such as the maintenance of very long range in all naval actions or the supposed disastrous effect of projectiles fired from very large guns hitting less frequently than the projectiles of smaller guns. Perseverance in that course of action becomes an obstinate madness, when the battleships armed on the single-caliber big-gun principle have to encounter other fleets which are equipped with powerful secondary armaments as well as with big guns. Some of the speakers said, with perfect truth, that the British Admiralty has been left in a position of having

adopted powerful secondary armaments in their latest ships. In my paper I preferred not to dwell upon that aspect of the question, although it is absolutely true. Recent statements made in the British press indicate that the force of the argument is now being recognized, and that 6-inch guns are likely to be reintro-troduced into British battleships. The chief reason given for their reappearance is that they are necessary in order to provide adequately against the attack of torpedo vessels. At the same time it is admitted that, when once moumted, these 6-inch guns will be used also in battle. So long as the guns are carried they can be used as thought desirable and no one need trouble much about the reasons given for their reintroduction.

Admiral Mahan endorses the view which I put forward that the power of concentrating gun-fire on an enemy is not lessened by carrying a certain number of heavy guns in a larger number of ships owing to the fact that at long ranges the larger number of ships bring their guns to bear effectively on a single point in the enemy's line. He also agrees with the opinion expressed in the paper that an increase of numbers of ships making up a fleet, when kept within reasonable limits, is advantageous as diminishing risks from under-water attacks and giving greater flexibility to the action of a fleet. Pushed home to its extreme form the argument in favor of the "monster" battleship carrying a big-gun armament would lead to the advocacy of a single huge ship of which the defense should be made practically invulnerable and the power of the individual gun irresistible; but when stated in that extreme form the absurdity of the position becomes obvious and no comment is required.

Advocates of the single-caliber big-gun armament and of extremely long fighting ranges take for granted the possibility of continued and deliberate control of the fire from the heavy guns from some central position in action and the communication of order therefrom to the several guns being as efficient and calm as they usually are under peace conditions or during battle practise. In my paper I indicated clearly the opinion that neither of these conditions would be fulfilled; and no one who is familiar with the delicate apparatus used for communicating orders from control stations to guns and batteries can believe that the apparatus would remain in order long under the conditions of action. In the heat of action operators in control stations can hardly be expected to perform their duties as coolly and deliberately as they do in peace practise; and I am glad to note that Admiral Mahan has emphasized this point forcibly and clearly.

Admiral Capps spoke very modestly of what was done before the Michigan arrangement of armament was decided upon; but as one who is familiar with the circumstances of that case I desire to put on record once more my sense of the high value of the work done at that time by the United States Naval Department and in particular by Admiral Capps and his staff. It was a bold departure to make, more especially after what had happened in connection with "interference" of the fire of the 8-inch and 13-inch guns in the Massachusetts class but with the modifications the precautions introduced into the Michigan system complete success was attained and that system is now rapidly becoming almost universal.

Naval Constructor Taylor and Professor Hovgaard appear to be in favor of triple turrets as compared with the usual twin arrangement. My own reasons for preferring the twin arrangement have been stated briefly, and I am inclined to think that most people who are familiar with what goes on inside a twin turret at battle practise will not think it probable that when a third gun has been added to a turret the rate of fire will be the same as with the twin arrangement. Certain additional and serious risks will necessarily be involved when that additional gun is mounted and worked, and these risks will be greater if the internal diameter of the turret is increased little if at all as compared with that of the twin turret. At the same time my respect for the ability as well as the boldness of Italian naval architects, and my knowledge of the fact that in working out the design for triple turrets they have been assisted by the unrivalled experience of the Armstrong firm, made me add that only experience in actual warfare could definitely settle the matter. I did not say, nor do I think, that experience could be derived from a single action. As a matter of fact I agree with the view expressed by Naval Constructor Taylor and recognize the fact that false deductions have been made repeatedly from the results of single actions. No one can have read the many articles and papers in which the events of the battle of Tsushima have been discussed without becoming convinced that all writers on the subject of warship design are disposed to find in the events of that struggle confirmation of their own particular views although many of the views expressed by different writers are diametrically opposed to one another.

Naval Constructor Taylor in his interesting remarks on the development of secondary armaments in my opinion misses the main point of that history. The introduction of powerful and numerous secondary armaments was made by the French when they began the reconstruction of their navy after the war with Germany and had to face the problem how best to deal with British turret ships of moderate freeboard and with their guns carried at a moderate height above water. These British ships belonged to what would now be called the "single-caliber big-gun armament type." The French with their usual sagacity decided to construct battleships of high freeboard, carrying four heavy guns mounted singly (in the positions described in the paper) and at a great height above water, and to associate with those four heavy guns a battery of guns of moderate caliber carried on the main deck. Experience in heavy Atlantic weather—when the British turret ships were not able to fight their heavy guns and had no other guns to fight with—showed that the high-sided French ships could efficiently use both heavy guns and secondary armaments. The British Admiralty recognized this fact and adopted the same principle as the French, but carried it out in a different way. From that time onward to the date of the Dreadnought's construction (1905), powerful secondary armaments formed an important feature in the armaments of all British battleships. I speak of what I know in this matter, having been personally concerned with it throughout the whole period in question.

Naval Constructor Linnard contributed to the discussion certain important

considerations, dwelling upon the necessity for giving adequate protection to battleships. In doing so he really endorsed views which I had expressed in a general form in the paper. My thorough conviction is that in many recent designs for battleships protection has been sacrificed unduly; and in my judgment the designs prepared in the United States Navy Department during the last five years are superior as regards protection to many, if not to most, of the contemporary designs for European battleships. An active and powerful offense is undoubtedly of great great value as a means of defense in a naval action. On the other hand if defense is unduly sacrificed, and if ships can be put out of action readily—by having their buoyancy and stability seriously lessened or their trim seriously changed by a volume of fire from comparatively light quick-firing guns—then in my judgment a proper balance of qualities of offense and defense has not been secured in the design.

Professor Hovgaard repeated in the discussion views which he had expressed elsewhere as to the desirability of providing good torpedo armaments and stronger protection against under-water torpedo attacks, in modern battleships. I agree with him in thinking that many admirals will be disposed to seek what may be described as the "decisive range" in action rather than to "play the game of long bowls" which advocates of single-caliber big-gun armaments prefer. But in my opinion the multiplication of torpedo-ejecting stations in battleships is not desirable, nor is it easy to provide the requisite space without prejudicially affecting other important features of a design. By some accident the section which appeared in the original manuscript of my paper and which dealt with the torpedo armaments of battleships was omitted from the proof used for purposes of reading and discussion. It has now been restored to its place in the paper, and will suffice as an expression of my personal view on this subject. In regard to the use of strong under-water armor protection against torpedo attacks, I consider that it has been demonstrated by actual experiments that such means of defense would not prove effective against modern torpedoes. The watertightness of the skin and structure of the vessel could not be preserved when such torpedoes got home against the bottom of a ship even if it were armored. It may be proper to recall the circumstance that Admiral Bacon (who is an ardent advocate of the single-caliber big-gun ship) made the striking admission in his paper on the "Battleship of the Future" read before the Institution of Naval Architects last April, that no ship, however large, could be expected to remain effective for further action after she had been struck under-water by a modern torpedo. Independently of that opinion I am convinced that experiments already made confirm the view I have expressed, and therefore I consider Profesor Hovgaard is unduly sanguine in supposing that any feasible scheme of under-water armor protection on the bottom of a ship can be devised and carried out. This statement of course is not intended to cast any doubt on the feasibility of building a ship of the dimensions and characteristics which Professor Hovgaard put forward a few months ago in the 1910 edition of "Fighting Ships."

THE CHAIRMAN:—Is there any further discussion on this paper? I wish to repeat that written discussion is invited, if you are not prepared to discuss the paper on the floor.

COLONEL STEVENS:—I move a vote of thanks of this Society for the very kind and admirable paper of Sir William White.

The motion was seconded, and on the motion being put the Chairman declared the same carried unanimously.

THE CHAIRMAN:—The paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President, will be taken up next.

The President vacated the chair and Colonel Stevens took his place as presiding officer.

# THE HISTORY AND ECONOMIC VALUE OF CANALS, WITH SPECIAL REFERENCE TO THE CAPE COD CANAL.

By Commodore J. W. Miller, Vice-President.

[Being a paper read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17, 1910.]

The title of our Society in its broadest significance includes all marine possibilities. Our organization and our personnel can only prosper as the scope of naval projects is enlarged. The architect must be the builder of ideas, the engineer the constructor of new thought before the resultants therefrom become physical facts.

Kindred associations, the Government and other societies are alive to the importance of the question of deeper waterways; therefore so much the more should we. This country is expending some seven hundred millions of dollars upon canals, while millions more are advocated for the betterment of our rivers, harbors and streams. Many of the plans proposed are excellent, others of doubtful advantage. It should be the province of this scientific society to encourage the former.

Eliminating from the discussion any narrow local, financial or commercial view of the subject, I will confine myself, in the first instance, to the influence of canals upon nations and communities, and then note how that influence has led this country to its present widespread thought upon the improvement of our waterways, and especially one of them which will be proved of immediate national benefit. From a casual study of the history of canals two facts present themselves:—

1. That a congested and interior population naturally seeks the sea for wider markets.

2. That wherever practicable traffic will ultimately reach the sea by water which has been, and again will be, the cheapest of all routes.

The truth of these axioms is to be seen from remotest time.

## I.

As early as 5000 B. C. an overcrowded Assyria and Babylon were seeking, through waterways, the ports of Asia Minor as outlets for surplus product and population.

Following the centuries for 2,000 years, we find the great Rameses, Necho, Ptolemy Philadelphus and Trajan, engaged in building up Egypt, and extending its influence beyond the sands of the Nile, and ultimately to the remotest part of the Roman Empire.

If we turn our attention toward Central Asia, we note the civilization of China thoroughly aroused to deep-water transportation as early as the seventh century, the advanced inventive genius of the Orient giving to canals the first "inclined plane," and, through a perfected system, opening the interior and providing it a vent to the sea.

Turning toward Europe we discover the earliest canals in the twelfth century, when Leonardo de Vinci built the first Italian lock and the Dutch constructed waterways through the marshes of the Netherlands. From these came the enlarged channels to ports, reclaimed from the sea, and from these ports a resultant commerce and navy which disputed with England the supremacy of the ocean.

France in the seventeenth century built the Briere Canal and supplemented it by the Lanquedoc, with its elevation of 600 feet, its tunnel of 700 feet, and a length of 148 miles. That country, through its magnificent perfected system, is to-day able to place its manufactures at a minimum rate, although Germany during the past twenty years has been striving to outrival her.

In England the first known canal was built by the Romans from Lincoln to the Trent. Abandoned at times, it was deepened in 1840 and still exists. Small of area, that country did not feel the need of interior waterways as greatly as her larger neighbors, and yet in the early part of the nineteenth century she built many. Today she is sending the manufactures of an over-crowded interior to her vast colonial systems through the Manchester and Caledonian canals, while the channel which she controls at Suez—conceived by the Frenchman De Lesseps, at or near the site chosen by Napoleon in his endeavor to recreate the former power of Egypt—and the one at Corinth testify to a far-sighted policy of shortening the marine routes of the world.

## II.

Keeping in view the countless ages of the past, let us trace the history of canals in this country, remembering that it is only 186 years since Dollier de Casson, a French priest, advocated river improvement at the spot where the Lachine Canal exists to-day, and that the first actual canal was constructed as late as 1750 in Orange County, New York.

A young Virginia engineer, previously on the Braddock campaign, was the first to advocate a canal company. It was George Washington who initiated the project of connecting the Potomac and the Ohio by an artificial waterway over the Alleghenies; nor did the revolutionary war diminish his interest in that enterprise. Senator Lodge says in his Life of Washington, "whether he was writing of canals or the Mississippi or the western posts he always was arguing and urging union and an energetic central government." Oliver, an Englishman, in his Life of Hamilton writes under the heading, "The Power of a Vision"—"In the early spring of 1785, a modest but memorable meeting took place at Washington's country seat, Mount Vernon, between representatives of the states of Maryland and Virginia. The occasion was a conference in regard to waterways between the eastern settlements and the western unpeopled land." It was necessary to unite the more or less disassociated states by some common cause. Spain held the mouth of the Mississippi; England had not given up the frontier forts. From the meeting at Mount Vernon followed, first the Annapolis, and then the Constitutional Convention at Philadelphia, and one of the arguments for a more perfected union arose through the rivalry between Virginia and New York as to which should obtain the first water route to the west and develop unknown regions for the benefit of the whole United States. Washington was the moving spirit and his foresight and greatness in peace are no more forcibly shown than in urging the construction of what, forty years afterwards, became the Erie and the Chesapeake & Ohio canals.

The war of 1812 hastened the building of the former, but we would go too far afield if we gave even an outline of the efforts of DeWitt Clinton to connect the Great Lakes and the Hudson. The improvement of natural bodies of water through a comparatively level country was cheaper than building roads in a primeval forest, and yet through the connected waterways that forest was quickly succeeded by the towns and villages which have made the Empire State; while immigrants poured westward to people the Ohio and Mississippi valleys. Whatever of financial profit or loss there may have been to individuals from the subsequent overbuilding of canals, they were of the utmost economic value to both the state and country.

Mention should also be made of the Raritan and the Morris canals, connecting the Delaware and Hudson, the latter built by Macculloch in 1830. They opened up the coal fields of Pennsylvania and served to make New York the city which it is to-day.

The third decade of the nineteenth century witnessed the period of greatest activity in canal building; the fourth, the application of steam

power to land transportation. Naturally the new and more mobile form of transit supplanted the slower one; the craze for railroads exceeded that for canals. The capitalist of the east sought profit in the growing west. The farmer, lured by the rich soil of the Mississippi valley, abandoned his New England home. The prairie schooner took the place of the coasting craft. The spirit, taught in the rugged school of the ocean, was transferred to the "conquering of a continent." The Atlantic coast lost temporarily its sea power, and New England, through the upbuilding of the interior, its vast marine possibilities, which up to that period she had continuously fostered.

III.

Chief among these possibilities was the betterment of the network of sounds and bays which line the shore from New York to Nova Scotia. Perhaps the most interesting marine locality is the great right arm of Massachusetts known as Cape Cod, interesting from an historic and patriotic point of view, ever since the landing of the Pilgrim fathers. Discovered by Bartholomew Gosnold in 1602, a Frenchman named DeMonts realized its dangerous shoals when, three years later, he named it "Malebarre."

From that date to this, Cape Cod has sent forth men whose names have been famous in all walks of life, while the county records of to-day show a purer Pilgrim strain of blood than anywhere else is to be found. There the Bacons, Cushings, Otises, Tuppers, Bournes, Nyes, Crockers and Keiths lived and still live. There engineers and naval officers surveyed. Collins there thought out the establishment of the first American line of steamers, while Webster, Cleveland, and Joe Jefferson lived there and fished in the neighboring streams.

During three centuries a canal has been advocated across the narrow sandy isthmus separating Barnstable from Buzzards Bay. As early as 1697, a committee was appointed to view the place, "it being thought by many persons very necessary for the preservation of men and estates" that the passage should be cut.

In 1776 Washington and the Revolutionary Council sent James Bowdoin and Machin there to see if a way by water could be found to avoid the enemy and the hazardous navigation around the Cape.

In 1780 General Knox made an estimate for a canal; then followed in 1791 the surveys of Winthrop and Hill, and in 1808 the report from Gallatin, Secretary of the Treasury. The names of Thorndike, Perkins and Loami Baldwin were associated with the project in 1881. Subsequent

government surveys were those of Major Perrault of the Army, and of Blake and Davis of the Navy.

From Colonel Foster's survey of 1870 there followed the charter to Russell Sturgis and C. H. Allen, and that of 1880 to the Cape Cod Canal Company of which Mr. H. M. Whitney was President. The government report of Colonel Warren made at this time contains the perfected survey upon which the present plans are based.

The Whitney Company having decided not to continue the work, the charter fell into the hands of Messrs Lockwood, Quincy A. Shaw and others who excavated over one million cubic yards near Sandwich, but were forced in the early part of 1890 to make an assignment to Col. Thomas L. Livermore.

The Lockwood charter of 1883 was supplemented by a new one on June 1, 1899, and under it the present company is working, it having been kept alive through the energies of DeWitt C. Flanagan, who had certain amendments made in 1900, and from 1904 to 1909, together with Charles M. Thompson of Sandwich, and others, endeavored to enlist financial interest in the undertaking.

## IV.

The results of heredity are nowhere more apparent than at Cape Cod. They have forced the inhabitant to water pursuits and drawn the western sons of New England back to the sea, both in body and in spirit. Many instances could be given to prove this, and why the whole nation is again looking seaward. Let us at least for a moment hark back to the story of two men, one the pioneer of commerce in New England, the other the ancestor of worthy descendants.

The time is the year 1627, and that of the rigorous winter when the Old Colony was threatened with starvation. The militant Miles Standish, now on a pacific mission, was sailing his "shallops" toward the country of the Shawmes; thence with his boats pulling up the Scusset River, a distance of three miles, he took his crew to an elevation of only 29 feet above the sea, and in the distance saw before him, anchored in the Manomet River, a small flotilla. This was commanded by a man named Isaac de Resieres from New Amsterdam. The Dutchmen had relieved the Pilgrims from starvation and, "trading there in sugar, linen and other commodities," the first commerce between New York and Boston began. From that day to this it has been maintained and increased through the joint endeavor of Massachusetts and her sons in the west and south.

A few years later, on April 3, 1637, Sir Edmund Freeman and nine others were the pioneers at the same spot where the commerce began. Unlike the fighting Standish he favored the new sect of Quakers. He had arrived at Lynn on the ship Abigail in 1635 and was subsequently seven times Assistant Governor at Sandwich. His daughter married a man named Perry who was also a Quaker, and his son married Perry's sister. From that union of Freemans and Perrys there ultimately came those distinguished fighters, General Nathaniel Greene, Christopher and Raymond Perry of revolutionary fame, and the two brothers Oliver Hazard Perry and Matthew Calbraith Perry, the naval fighters of the war of 1812; the latter, who opened up the trade of Japan to the world, was the grandfather of the man who is now building the channel near the home of his ancestors.

## V.

I have shown the economic results of canals upon foreign countries during the long ages of the past, and that they have been of benefit to the United States at large. The fact, however, must be kept distinctly in mind that in this country of magnificent natural water courses their improvement has been limited to a trifle over a century, and that we have seen the introduction of steam—a power that temporarily checked canal building. The time has now arrived when water transportation will find its own again.

The railroads, heretofore antagonistic, are to-day unable to carry the crude products of the country, and are in favor of canals. Two notable examples may here be cited.

Fifty-two years ago the Sault Sainte Marie canal was opened when the railroads had a monopoly of the Great Lakes traffic. Minor freight agents and railroad officials made whatever rates they chose, while rivalry between competing corporations reduced those rates until combinations led to "systems," when the tariff was again raised. This rivalry resulted in the shippers of the lake region becoming restive and initiating water lines; they were fought by the railways until the broader and higher officials saw the wisdom of using the parallel lakes for the movement of raw material, the result being to-day the numerous fleets working in harmony with the land routes to the advantage of all concerned. Thus, in 1857, the wisdom of the advocates of the Erie Canal in 1825 was again shown, and to-day New York is building a deep-draught barge route to cost one hundred millions of dollars.

It is for wise statesmen to say, in view of what Canada is contemplating, whether or not there should be a depth of 25 feet from the Great Lakes to the Hudson.

Nearer home we have an equally notable example on Long Island Sound. Here also a body of water parallels one of the most powerful corporations of the country. That corporation has fostered "this multiple trackway free to all" to the great benefit of its land lines. It has recognized the vital fact that cheap freight must be brought into the eastern states at a minimum figure. In no other way can the population of a manufacturing region in a locality devoid of cotton, iron or coal continue its industries. If New England is to retain her prosperity, she must continually foster water transportation. Massachusetts especially should be alive to the fact that while government bureaus are publishing reports, while associations are discussing future policies, actual work is being done by a corporation within her borders upon the channel, advocated by her earliest settlers, and that the Cape Cod Canal will be finished in 1912.

No better examples that a "congested and interior population" must seek water routes can be given than those quoted above.

The commerce of the former has been increasing by leaps and bounds, and the time has arrived for the construction of the Cape Cod Canal as the northern section of the first of the series of channels which will ultimately be built to carry domestic commerce to connect with the foreign trade passing through the Panama Canal.

Thus far the attempt has been made to prove that history and heredity both point to the time being ripe for improved waterways.

The heretofore numerous attempts to create a merchant marine for this country have been abortive, but it would seem that the present movement, emphasized by the meetings and agitation of the past year, may lead to tangible results, through the reflex action from the west toward the east in favor of water transportation.

## VI.

We now naturally come to a description of the Cape Cod Canal.

From an engineering point of view, the problem is not great. The total length over the isthmus is 8 miles. The total length to 30-feet depth in both bays is 13 miles. The soil to be cut is sand, and amounts to 17,000,000 cubic yards. The deepest cut is 29 feet above tide-water. The channel at both ends of the route, the natural marshes and streams already furnish a waterway for boats of light draught. The difference in tide between the two bays necessitates no locks. The depth of the canal is to be 25 feet. The minimum width of bottom will be 100 feet through the central portion of the canal, and this will give a surface width at the narrowest point of

250 feet. The approaches will have a minimum bottom width of 250 feet. The right of way has been obtained, and in addition other tracts of land essential to the undertaking.

Agreements for the change of the railroad line have been made with the N. Y., N. H. & H. R. R. Co.; the railroad bridge necessitated thereby is completed; four dredges are deepening the five-mile western approach from Buzzards Bay; two large suction dredges are removing about 20,000 cubic yards per day for the channel through the marshes at the eastern end of the canal.

A breakwater, 3,000 feet in length, is being built northward of the channel, where it enters Barnstable Bay. Several other dredges are at work on the central portion of the line. Administration and other buildings have been bought and the necessary preparation made for a campaign of activity on the ground during the coming winter.

The bridges are being constructed on the basis of an ultimate depth of canal of 34 feet. They will each have an opening of 160-feet span of the type known as the Bascule lift bridge. The local travel across the canal will be accommodated by such bridges or ferries as experience may dictate.

The final estimates for the canal include the thorough electric lighting and other aids to navigation of the whole channel and approaches requisite for a region where fog prevails.

The tonnage through Vineyard Haven Sound to-day, which will be all tributary to the canal, amounts to 25,000,000, of which there is:—

| | *Tons.* |
|---|---|
| Coal | 9,000,000 |
| Stone | 300,000 |
| Nova Scotia plaster | 250,000 |
| Oil | 200,000 |
| High-class merchandise | 2,000,000 |

the remainder being crude material of various descriptions.

The number of passengers between New York, southern and eastern points by water is to-day over 500,000. This number will be greatly increased through the opening of the canal, as the neighboring regions will be much more accessible, and steamers of the Sound type can leave New York late in the evening, land their passengers at desirable resorts, and arrive at Boston early the next morning.

The N. Y., N. H. & H. R. R. Co. runs along the southern bank of the

canal. A large manufacturing center will be developed at the eastern end, where mills will have the advantage of both land and sea transportation. Water abounds in the hills back of the center of the line, and on these hills an increasing summer population will undoubtedly be settled.

Skepticism as to the success of the canal has been natural, being based on the conditions of the past, when the great majority of the coastwise tonnage was carried in sailing vessels.

To-day—

(*a*) This tonnage is under the control of a small number of corporations, which tow the merchandise in barges containing from 1,000 to 3,500 tons.

(*b*) The towing companies now require a plant for a three-weeks round trip on account of the dangers and delays via the Vineyard Haven route.

(*c*) The cost of this plant will be reduced at least one-third, for the reason that not only is the distance shortened sixty-six miles, but the duration of the trip is greatly diminished.

(*d*) Insurance from perils of the sea will be lessened.

(*e*) The congested railroad systems of the Atlantic coast are now heartily in favor of water transportation for crude material, thus relieving their lines for the transportation of high-class merchandise and passengers.

(*f*) This new waterway is not in the strictest sense a canal, but a short passage connecting two portions of a much-traveled route through which a known traffic exists. Its conditions are analogous to those at Suez, where the profits have far exceeded the estimates.

(*g*) Humanity demands the elimination of the dangerous, stormy and fog-bound route around the Cape. The loss of life and property in that locality has been appalling. The record, more or less incomplete, from 1843 to 1903, gives a minimum of 2,131 vessels wrecked in the Nantucket Shoals region, 908 of which were total losses. Ten complete crews disappeared with their ships, and in addition, about 700 men lost their lives.

The completion of the canal will render unnecessary the proposed dredging of Pollock Rip channel at an estimated cost of some three million dollars, a sum which could be much more advantageously used by the Government in the neighborhood of the canal rather than being wasted in the tortuous and ever-shifting channels off Chatham.

Such is the description of the work being done by the Boston, Cape Cod & New York Canal Co., a corporation which is expending twelve million dollars under a charter granted by the State of Massachusetts on June 1, 1899. Its promotors are assured that it will be a financial success. The writer shares their opinion, and is proud, as an ex-navy officer, to be asso-

ciated with a company, the forerunner in the construction of a series of canals which will be potent factors in the problem of regaining for this country the old colonial spirit of the ocean. Our merchant marine, taught among the shoals of Cape Cod, but dormant for half a century, will, if the signs be right, once more encircle the globe. The recent renewed love for our great navy, as well as history, proves this, and all should join with helping hand and voice in this and every effort toward bringing the thought of the United States "back to the sea."

## DISCUSSION.

THE CHAIRMAN:—Is there any discussion on this paper, gentlemen?

CAPTAIN THOMAS I. MILLER, *Associate:*—Mr. Chairman, I would like to ask a question about a point which I consider important, and that is as to the prevalence of fogs in the upper part of Buzzards Bay as compared with the Nantucket Shoals. This is a matter which will have a very important bearing upon navigation, and also, as Commodore Miller very well knows, additional lighthouses and lightships will be required to make this new waterway comparatively safe.

COMMODORE MILLER:—Fogs are of course prevalent along the New England coast, but they are much less dense in Buzzards Bay and Barnstable Bay than they are off Cape Cod or in Vineyard Sound. Recognizing, however, that there must be the utmost mobility through a narrow strait connecting two important waterways where commerce demands speed for both night and day traffic, we are giving the subject of lighting the canal most serious attention. We must make it attractive for the whole twenty-four hours. We are therefore in communication with one of the foremost electric light companies upon the basis of what I may term "street illumination," including the approach in Buzzards Bay to the end of the breakwater at the eastern terminus. If this plan can be carried out there will be a white lamp every 400 or 500 feet, throwing its reflection upon the channel, and a green and red one designating the shores. The principle is to have marked spots and buoys and to avoid horizontal rays which are blinding to pilots.

MR. E. PLATT STRATTON, *Member:*—Mr. Chairman, there is one question I would like to ask the author of this paper regarding the depth of water in this canal—25 feet. It seems to me this is a depth that will hardly meet the requirements of our battleships, and Captain Miller has referred to the fact that the bridges over

this canal have foundations extending 35 feet under water; hence I am inclined to believe that it would be desirable if the depth of 25 feet could be increased to accommodate vessels of a draught of at least 35 feet. The Panama Canal is to have 40 feet of water in it, and as the Cape Cod Canal will certainly have to accommodate a large majority of all the commerce passing by sea from Boston to New York and *vice versa*, I incline to the belief that the promoters of this great enterprise should seriously consider a draught of water of at least 30 feet, and still better 35 feet, and as the material to be removed can all be handled by dredges, and transported by scows, the increased cost will be much less in proportion than it would be if excavated dry and the soil transported by rail.

COMMODORE MILLER:—The matter of depth of the canal had very grave consideration on the part of the corporation of which I have the honor to be vice-president. Ours is a commercial company building a waterway for the coast-wise commerce of the United States. This commerce necessitates not more than twenty-five feet depth at low water. From a business and financial point of view we see no necessity of any deeper channel. May I say incidentally that, considering the skepticism of the past, the Belmont syndicate is showing wisdom in so doing. The people, the Government and the State of Massachusetts should appreciate that while other organizations are demanding aid, we are building this first of the Atlantic coast canals with our own resources for the merchant marine of the country and the coast. If the Navy wishes a thirty-four or forty-foot canal we will, however, as patriotic citizens be ready to listen to any proposition that the Government may make. Foreseeing that there may be some possibility of deepening the canal for battleships at some future period, we are going to the great expense of making the foundations of our bridges deep enough for such a contingency, and are about to place our wharves sufficiently far back from the center of the canal so that they will not interfere with any greater depth required by the Navy. Such is my answer from the business, financial and commercial side of the question.

If it were put to me as vice-president of this Society, and an ex-officer of the Navy, my answer would be as follows:—

While well aware that the place for a battleship is the open sea and off shore, still I can conceive of some crucial moment when the squadrons at such strategical points as New York, Boston and Narragansett Bay should be united with the utmost celerity as a fleet to quickly oppose a united enemy of large force. In such an event if the canal were thirty feet in depth at low water, 150 miles could be saved over the route outside of Nantucket, and such saving warrants the additional outlay of about $3,000,000, and I will venture to prophesy that that extra depth will eventually be made and at a cost far exceeding what it can be done for during the present process of construction. It would be a trifle if it insured a victory by uniting squadrons in the time of need.

Again, the Government has now under consideration the deepening of the

shoal and fog-bound passage around Cape Cod, known as Pollock Rip Channel. This will cost at least $3,000,000, and the shifting sands in that region will close it within a few years. This channel will be useless after the completion of the canal; it will be a waste of money to put it there, therefore in one sense the deepening of the canal will cost the Government nothing.

MR. EDWARD P. BATES, *Member:*—Mr. Chairman, the writer has referred to DeWitt Clinton and Robert Fulton in a general way in this paper, and I have heard it stated that Robert Fulton was a consulting engineer for DeWitt Clinton in the laying out of the Erie Canal. I have never come across any such authority myself and I would be very glad if any member here who has knowledge of such authority, or if he finds any such authority, would communicate it. Robert Fulton, I believe, died nine years before the canal was completed.

COMMODORE MILLER:—Referring to Mr. Bates's question—how far DeWitt Clinton used Robert Fulton as designing engineer—I am unable to state. I do know, however, that he supplied general designs for the inclined planes to President Macculloch of the Morris Canal in New Jersey, and these inclined planes still exist. DeWitt Clinton and Professor Renwick were advisors in that enterprise, and John C. Calhoun, Secretary of War, gave the services of General Barnard.

At the ceremonies incident to the opening of the Erie Canal off Sandy Hook on November 4, 1825, the following toast was given:—

"To the memory of Robert Fulton whose mighty genius has enabled us to commemorate this day in such unparalleled magnificence and grandeur."

From which quotation it would seem that Fulton prior to his death was an advisor to DeWitt Clinton.

THE CHAIRMAN:—Are there any further remarks? If not, the time having arrived for luncheon, the Chair will announce that Mr. Cramp's paper, "The Evolution of Screw Propulsion in the United States," will be read by Mr. Forbes immediately upon reassembling at half past two.

The Convention thereupon took a recess.

# EVOLUTION OF SCREW PROPULSION IN THE UNITED STATES.

By Charles H. Cramp, Esq., Vice-President.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

## PART II—AMERICAN CLIPPER AND LARGE PADDLE-WHEEL STEAMERS.

The period of the greatest activity in shipbuilding in this country, as far as the hulls were concerned, which were all of wood, was between 1849 and 1860, and it was about that time that iron had begun to take the place of wood in Great Britain. It was at the close of the demand for a high class of vessels, which originated during the famine in Ireland, that gold was discovered in California. This necessitated quick transportation for trade and travel, and the great American clipper, which had been introduced in the East India trade, had developed into the highest state of perfection ever attained in the art. The investment due to the favorable conditions of the time was a correspondingly profitable one. This might also be said of certain paddle-wheel steamers that began to make their appearance about the same period.

During the excitement, while rates for passengers and freight were high, all kinds of inferior or obsolete vessels were sent out to California at a handsome profit and most of them were permitted to remain in the Bay of San Francisco until they rotted or were destroyed.

Soon the clippers, and afterwards the steamers, began to swarm there; charges had begun to settle down to a regular basis which still continued high—about a dollar a cubic foot for freight, with passenger rates at as high a range. Many clippers cleared themselves on the first voyage; they were mostly built in New England on speculation and were sold at extravagant prices. The charges for freight and passengers were a great stimulus to the introduction of the high class of paddle-wheel steamers in the trade there, and, notwithstanding the cost of running them, they became very profitable.

Both of these classes of ships, particularly as far as the hulls are concerned, were by all means the greatest and most interesting specimens of naval architecture that the world has ever witnessed; not only as traders, but for the beauty and gracefulness of their design, completeness of their equipment, and seaworthiness. This superiority not only extended to the hull of the ship and shipbuilder, but to the spar-maker, the rigger, the ship-joiner and all others connected with the equipment and outfit. We must

also include the commander and his officers within the scope of this superiority and efficiency.

As the overland travel began to increase the usefulness of the clipper in the California trade began to wane and lines of fine paddle-wheel steamers were placed on each side of the Isthmus. Later on the clippers stopped at Peru for a return cargo of guano. All of this aided in prolonging the existence of the side-wheeler and of retarding the introduction of the screw.

A number of paddle-wheelers later extended their trips to Australia and China, but the machinery, which did not function well on short trips, failed on these long trips.

A trip along the wharves of the East River during this period was an interesting one. Besides the large packet ships and steamships there were to be seen the skysail and moonsail yards of the large clipper ships, a noteworthy sight.

In addition to the ships there, one would see a captain of one of these ships in all his glory; he was the cockiest looking man to be found; he was always handsome and well built, well dressed, and looked his part well.

The great character and high standing of these ships, with all relating to them, began in 1853 to lose that important position they had acquired before that time. There were many reasons that contributed to their impending downfall. The introduction of steam and the inability and neglect of our people to take proper advantage of the correct methods of its application, and the introduction of iron in the place of wood were the principal reasons for it. The profitable traffic in the carrying trade was on the retrograde, owing to the increasing facilities and falling away of demands due to the approaching civil war, and when that war commenced there was an end to that part of the shipping industry, as the Government bought at liberal prices most of the steamships that remained. If the shipping merchants and steamship companies of New York, as well as the engineers of that place, would have encouraged the start made by engineers in Philadelphia, the destruction would not have been so complete.

## WARSHIPS FOR NAVY.

As soon as the civil war had begun, shipbuilders began to replace some of the vessels taken by the Government and devote their energies to contracts with the Government for navy and transport services. The Navy Department, through Assistant Secretary Fox, concluded to build a number of armored vessels, in view of what had been done by the French in the Crimean war, and what the British had been doing since in the way of building them.

In accordance with his recommendation, Congress made an appropriation for them and Commodores Smith, Paulding and Davis were appointed a board to carry out the purpose. They advertised for proposals, to be accompanied by full specifications and drawings, and also with the price.

The advertisements were responded to by about thirty proposals of the most extraordinary and outlandish character, and as illustration of the retrograde in everything relating to naval architecture and steam propulsion in New York, three of the great builders from there proposed to build a ship for a certain sum of money, without a single drawing or scrap of specifications as to dimensions, material or performance accompanying them. They affected to be above troubling themselves as to matters of mere detail and maintained a lofty attitude throughout.

The only complete proposition accompanied by drawings with full specifications as to dimensions, and with size of armor, speed and time for completion presented, was that of the New Ironsides, which we furnished, and it was at once accepted, and as the price was less than the appropriation the Board decided to accept the two other propositions whose sketches and details were fuller than the others. The cost of these ships exhausted the appropriation. They were those of the Monitor and Galena, and the object of the Board, as they stated it to me, in taking them was in the way of an experiment. All of these vessels were propelled by screws.

The contract for the New Ironsides was in the name of Merrick & Sons who furnished the engines and armor. At that time engine building was not included in any of the shipbuilding works. The suggestion that we should join in their proposal was made to me by Mr. B. H. Bartol, superintendent of Merrick & Sons.

When we built this ship it was in direct correspondence with the Department and it was according to our drawings, which were in the fullest detail of rigging, spars, sails, etc., and the same detail was observed by Merrick in the engine installation.

The building of the New Ironsides, Monitor and Galena was an event that led to the effectual and final destruction in this country of the great shipbuilder whose career and occupation had been so distinguished in connection with the great packet and clipper, and had covered him with so much glory. I refer to the commonplace but important incident of the battle between the Monitor and the Merrimac. Both of these vessels were curious specimens of the shipbuilding art. The Merrimac was an old American warship of wood which was cut down and a sort of raft-like upper works built upon her, and badly done at that. Her battery was poorly protected and was practically *hors de combat* on the first round with the Monitor.

The Monitor was built by parties who had never built a warship and had little experience with iron hulls. During its construction we were requested to send men over to bend the keel pieces, which were dish-shaped and bent hot, and other matters of difficult workmanship.

This victory over the Merrimac, coming as it did while the whole country was aroused over the sinking of the Congress and Cumberland, was the cause of one of the greatest excitements in shipping circles that the world has ever witnessed. Ericsson, with all of the officers who were on the Monitor during the fight, became the subjects of the most extravagant demonstration of hero worship. The Monitor craze carried everything before it, and even those whom I have reason to believe were not stampeded had to give way, so that, for a time, the Monitor was looked upon as the only war vessel, and only monitors were contracted for by the Navy Department.

It was common talk among contractors that the drawings supplied them for machinery of Ericsson's own design were mere sketches, and that he could not be induced to examine the contractor's detailed drawings or the machinery itself while under construction. Some were unkind enough to say that this was a clever plan to avoid responsibility for the machinery if anything went wrong, as he could claim that his drawings had not been properly adhered to. His friends, of course, denied this; and some even asserted that this practice was an evidence of the genius and greatness of the inventor.

The builders of these monitors accumulated fortunes in their work owing to the high prices they had secured and in the easy time they had in fulfilling their contracts. They believed it was owing to their own capability in money making and in shipbuilding. After the war some organized new steamship companies, and some went into shipbuilding, both of these occupations being busy in replacing ships that the Government had taken, or had been lost; others went into railroad building in the west—all became ruined financially. The railroad, shipbuilding, and steamship companies that continued after the war were, with certain exceptions, those that existed before it.

### THE FIRST IRON BOAT BUILT BY WM. CRAMP & SONS, THE LEHIGH.

Having been convinced at an early date that we should take up iron shipbuilding, we commenced in it by building the side-wheel tow-boat Aspinwall to take the place of the Lehigh. The engines of the Lehigh were transferred to the new one by the I. P. Morris Company. The large coal

companies still continued to use the side-wheel tow-boat to tow their large fleet of canal boats. Previous to 1847 all towing was done by the paddle-wheel boat, mostly by old ferry-boats; these were to be found everywhere in the United States and Cuba.

### THE FIRST SCREW TUG, THE SAMPSON.

The New Jersey was engaged in towing on the Delaware, and was being repaired at Reaney & Neafie's.

Mr. Michael Malloy, who was engaged in towing vessels to a point below the Horse Shoe on the Delaware with old ferry-boats, after witnessing the work done by the New Jersey, and with our recommendation, concluded to build one to do their work. We built the Sampson for him, of wood, and Reaney & Neafie built the engines. She proved a success and Mr. Malloy parted with his old ferry-boats, and all others in Philadelphia who followed towing did the same. The Sampson was the first screw tug-boat built in this country, and in connection with Reaney, Neafie & Co. we built a large number for all parts of the United States.

After building the Aspinwall we built the iron hulls of several unimportant vessels, when we joined Neafie & Levy in the construction of a good-sized ocean screw steamship, for sale. Neafie & Levy had full control of the machinery and we had full control of the hull complete, the price of both having been fixed at the start. Mr. Thomas Clyde joined in the scheme and secured her when finished at the prices fixed; her name was the Clyde.

After that we concluded to add engine building to our plant, and we secured the services of Mr. J. Shields Wilson, referred to in Part I, as the engineering head. The time was very favorable, as the great question of the use and utility of compound engines had begun to agitate the engineering world. This question was new and one that had been taken up by John Elder, who successfully introduced it in several new lines of steamers in England, and by MacFarland Gray, Engineering Member of the Board of Trade in London, who handled the subject with much skill in "Engineering," a periodical that favored it.

Mr. Wilson, who at that time was the ablest marine engineer in the United States, had interested himself at the very beginning of the agitation, had followed it up and had become so much convinced of its merit that we prevailed on Mr. Thomas Clyde to make a beginning, and he contracted with us to build the George W. Clyde, the first ship built in this country with fore-and-aft compound engines.

The success of the experiment on the George W. Clyde was greater than we expected, and we concluded to build compound engines and not consider any other type in our business as builders of complete steamships.

Mr. Clyde was never backward in joining in any new device of merit when recommended by parties in whom he had confidence.

Mr. B. H. Bartol, who had been a partner of Merrick & Sons, had also become a convert to the superiority of the compound engine, and afterwards was a prominent factor in its introduction.

### PENNSYLVANIA, OHIO, INDIANA AND ILLINOIS.

When a new Philadelphia company was started in 1871 in connection with the Pennsylvania Railroad to build a line of steamers to Liverpool, Mr. Bartol, on account of his business ability and his experience in steamship matters, particularly in matters relating to engineering, was made a director of the company and chairman of the committee to provide for the new ships.

He stated to me that, notwithstanding that we had every chance of getting the new ships, he would not agree to accept any device in construction except those of the most approved type, and he agreed that his company should pay us $10,000 in the investigation of everything new in steamship construction, particularly as to getting all the facts pertaining to the compound type of engines in Great Britain. Mr. Wilson and I made an exhaustive trip, beginning at Birkenhead and ending at Glasgow. As we passed on from one place to another, we found a majority against the compound, which afterwards determined us in favor of it. We soon discovered that the opposition to it was owing to the fact that the change of type would entail a great expense—all of their drawings would have to be changed, their patterns would be worthless and a great loss would be incurred, as they did not believe the benefits said to be derived from the new departure would reimburse them for their losses.

When we arrived at the Fairfield Works of Mr. John Elder, we saw and were permitted to examine thirteen compound engines in various stages of finish, and after we had been entertained by the members of the firm we departed at once for Philadelphia, having spent half of the ten thousand, and reported favorably to Mr. Bartol, who promptly executed the contracts for the Pennsylvania, Ohio, Indiana and Illinois.

Mr. Wilson and I were received with uniform kindness and politeness at every shipyard in Great Britain, and every opportunity was given us to investigate everything that each had done; if our trip had been a royal

one, we could not have been better received, and this will apply to the Admiralty and their dockyards as well.

The building of these four iron ships, between 1873 and 1874, was an event of much importance, particularly as the ships were propelled by screws and the engines were of the John Elder type of compound engines. The ships were subjects of much consideration on their arrival in Liverpool, many of the principal shops sending their draughtsmen to look up the flanging in the boiler heads and fire boxes of the boilers; no flanging of these or any other part of a boiler had been done before in Great Britain. They also took some trouble to examine the white metal in the bearings of these ships. We afforded them every facility in aid of their investigations as to flanging methods, the use of white metal, and in every other matter they interested themselves, as a return for their favorable reception.

The names of the vessels proved to be of considerable interest to two Liverpoodlian "wharf rats," who saw the Ohio pulling into the dock. One said to the other, "What does that beastly name spell—a ho and a haitch and a bloody ten?" The other could not inform him so they gave it up.

## JOHN ROACH.

The works of Reaney, Son & Archbold at Chester were afterwards taken up by John Roach & Son in 1872. Mr. Roach, who was an engine builder in New York, by profession an iron founder of prominence, had built there a number of engines for the Navy during the civil war and a short time after. He was bold and fearless and was in possession of great mercantile and commercial instincts. He became a conspicuous advocate of screw propulsion and he handled his old fogy neighbors, the paddle-wheel advocates, without gloves.

He induced two steamship companies to add new screw ships to their old ones. The Pacific Mail ships were still operated by certain interests outside of the shipping business, but under a style much reduced from its former lofty standing. Mr. Roach built a number of screw ships for that company. The final elimination of the paddle-wheel engine in New York was largely due to his efforts.

Mr. Roach's removal to Chester practically ended important hull building in the New York district; although he and others continued to build marine engines.

## DISCUSSION.

THE PRESIDENT:—This paper is before you, gentlemen, for discussion.

Mr. W. I. BABCOCK, *Member of Council:*—I think it is somewhat unfortunate that Mr. Cramp has not given any dates in his paper. He speaks of a good many old vessels., but it would be much more valuable if he had given absolute dates in connection with them. He says that the Sampson was the first screw tug-boat built in this Country, and that he built the Sampson, but he does not say in what year.

I have a letter here from one of the members of this Society. Mr. J. J. Lynn, of Port Huron, Michigan, and he has asked me to read the following:

"It may be of interest to have you mention that it is a question if the Sampson was the first screw tug-boat, the Reindeer having preceded her by three years. The Sampson was well known on the Lakes, if this is the boat Mr. Cramp refers to. The machinery was built in Philadelphia, and she was said to have come from the salt water. I would imagine that she was about one hundred and twenty feet over all, nineteen feet beam, and ten and half hold. She was a straight low pressure and in her day was called lazy, principally because she worked non-condensing and made no fuss as the other tugs did, consequently she was unpopular and her work was confined to towing rafts and barges. At this she was a marked success because she carried the largest amount of fuel of any of the boats then in operation.

"The Reindeer was brought here from Lake Ontario by Captain Sim Keeler, who afterwards took her on to the St. John River, Florida. Her engines were double cylinder, oscillating, on an incline of forty-five degrees, and had an outside fired boiler, the boiler set on brick work and the return was made through the flues, the flame passing on the shell, thence into the flues and stack, into the atmosphere. I recently talked with an engineer who was aboard of her when she was in service here, who claims that she was an older boat than the Sampson."

CHARLES E. HYDE, *Member:*—Mr. President, as a contribution to the early history of screw propulsion, I submit the following relative to the first Iron Sea-going Steamer built in the United States. In 1844 there was organized in Bangor, Maine, the Bangor Navigation Company, having as its object the building and operating of a steamer between that port and Boston, the following named persons forming the Company: Joseph Bryant, Jacob Drummond, Albert Emerson E. C. Hyde, James Jenkins and Edward E. Upham. One of the Company having been appointed manager, he was sent on a tour of observation down the coast, and after having looked over the steam navigation field of that day and visited several

shipyards, he strongly recommended building an iron steamer propelled by twin screws as being the most suitable for the service. Acting upon this advice, a contract was made with the firm of Betts, Harlan & Hollingsworth, of Wilmington, Delaware, for a vessel of the following description:

Length, water line, 125 feet.

Breadth, 23 feet 6 inches.

Depth of hold, 10 feet.

Rig, 3 masted, for and aft schooner with bowsprit and standing gaffs.

Machinery, twin screw consisting of two single engines, 22 by 24-inch cylinders.

One drop flue boiler.

Stateroom and berth accommodations for about 150 persons.

The keel was of 7–16 inch plate.

Hull plating, $\frac{1}{4}$ inch to $\frac{3}{8}$ inch thick.

Frames, flat bar iron, 3 inches by $\frac{3}{4}$ inch, spaced 20 inches, to which the plating was secured by U-shaped clips, or keepers, one foot apart, rivetted to the plates.

The price of the hull, based on a weight of 94,447 pounds at $9\frac{3}{4}$ cents per pound was $9,208.58.

Price of machinery, $7,650.00.

Separate contracts were made for carpenter and joiner work, rigging, painting, etc. The toal cost of the vessel, ready for sea, was about $21,000.00, an itemized bill for which, submitted by the builders, is in the possession of the writer.

The propellers were $8\frac{1}{2}$ feet in diameter of the "Loper" type, for the use of which the patentee was paid a royalty of $530.00. The increased cost of living seems not to have obtained in the matter of propeller wheels since 1845.

The vessel was about 7 months in building, was named the "Bangor," and at a builder's trial on the Delaware July 25, 1845, showed a mean speed of 11.56 miles per hour, with steam pressure of 46 pounds.

She then went on the route between Boston and Bangor, and on her second trip, when entering the Penobscot River, fire was discovered in the cargo, which spread rapidly to the woodwork of the vessel which was entirely destroyed. She was beached as soon as possible after discovery of the fire and no loss of life occurred. The finances of the Company did not survive the wreck, and the boat was floated and rebuilt by other parties and taken South where, under the name of "Scourge," she was used by the Government as a transport in the Mexican War. At the close of that war she was sold in New Orleans after which time all record of her seems to have been lost.

THE PRESIDENT:—If there is no further discussion on this paper, we will pass it, with the usual thanks to Mr. Cramp for the interest he has taken in the subject. The paper "Floating Dry Docks in the United States; relative value of wood and steel for their construction," by Mr. William T. Donnelly, Member, we will take up now.

# FLOATING DRY DOCKS IN THE UNITED STATES; RELATIVE VALUE OF WOOD AND STEEL FOR THEIR CONSTRUCTION.

By William T. Donnelly, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

While the floating dry dock is not by any means new in the United States, and while it is generally admitted to be an American invention, the application of technical knowledge or the skill of the engineer has so recently been called upon for its design and construction, that the writer feels almost bound to offer some historic references before taking up the special features which it is desired to bring particularly to your attention.

The oldest available record is a copy of a patent to J. Adamson for floating dry docks, December 13, 1816 (Plate 13). For a description of this and of subsequent types of wooden floating dry docks which have been developed in the United States, the author refers to a paper read before the Brooklyn Engineers' Club under date of January 25, 1905; and for an excellent detailed description of large floating dry docks built for the United States Government prior to 1850, parties interested are referred to "Naval Dry Docks of the United States," by Charles B. Stuart, Chief Engineer of the United States Navy. This is one of the most valuable works in existence, not only as regards floating dry docks but basin docks as well, giving such an excellent description of the construction and difficulties overcome in the building of the first basin dry dock at the Brooklyn Navy Yard as would be appreciated by those who have had the later construction under their care.

For the most modern description and record, bringing the history of floating dry docks in this country up to the date of the completion of the steel floating dry dock Dewey, reference can be had to the book entitled "Floating Dry Docks," edited by Sven Anderson, M. E., Superintendent Floating Dry Dock Department, Maryland Steel Co. This work is a careful compilation of recent papers delivered before the various engineering societies in this country.

Special reference should be made to very important papers by Civil Engineer A. C. Cunningham, U. S. N., and Civil Engineer Leonard M. Cox, U. S. N., the latter paper dealing with Naval Dry Docks and being a most complete presentation of mathematical and structural problems. This

paper will also be found in the Transactions of the American Society of Civil Engineers for 1907.

In 1906 the author was retained by a large dry docking and ship repair company to prepare plans for a floating dry dock. The general requirements were that the dock should ultimately have a lifting capacity of 20,000 tons and that approximately 12,000 tons lifting power was to be built at the beginning and added to later on.

While the author's experience had previously dealt with wood as a structural material for floating dry docks, he was also familiar with steel for such structures, and owing to the fact that all docks of approximately this size had been built of steel, attention was directed to that material, and a careful study made resulted in the selection and design of the Rennie type of dock with steel pontoons and wings (Plate 15), the pontoons being 14 feet deep, 28 feet long and 127 feet wide.

By reference to Plates 16, 17, 18 and 19, the general construction of these pontoons will be clearly understood. The steel wings were to be 40 feet high to give ample longitudinal rigidity. The details of this dock were very carefully worked out so that accurate weights were arrived at. They were 6,600 tons for the pontoons and 2,700 tons for the wings, or a total of 10,300 tons for the structure, which, on a basis of 20,000 tons lifting power, gives as a factor of structural weight relative to lifting power, of 5 : 10, which agrees fairly well with other large docks previously designed and built.

The fact that a working stress of 12,000 pounds per square inch was used throughout and that the wings of the Rennie type of dock were made of exceptional depth to insure longitudinal rigidity, will account for a somewhat higher weight factor.

While this dock was not built, bids which were received indicated that the cost of the dock completed would be approximately $57 per ton of lifting power. For a more complete description of this dock and the novel method of pumping by compressed air which it was intended to use, those interested are referred to a paper entitled "A New Method of Pumping Floating Dry Docks," read before the Brooklyn Engineers' Club on May 9, 1907. The reason for introducing the matter here is to effect a comparison between this structure and similar docks with wooden pontoons.

Referring to Plate 20, there will be seen a pontoon dock of 7,000 tons lifting capacity, with steel wings and wooden pontoons. The detailed construction of the wooden pontoons is shown in Plate 21. These pontoons are 100 feet long, 11 feet deep and 32 feet wide. Each pontoon has eleven frames or trusses on 3-foot centers. Top and bottom planking is 4-inch,

the side planking 5-inch and the end planking 6-inch. 6″ × 8″ deck timbers are worked across the 10″ × 10″ truss members on top and bottom in such a way that it is possible to get in the $1\frac{1}{8}$-inch double tie-rods without boring, and so arranged that they can be replaced at any time.

The material is merchantable grade of yellow pine lumber throughout and the fastenings are all galvanized. There were required for each of these pontoons 135,000 board feet of lumber.

The steel wings of this dock are 368 feet long by 30 feet high, 12 feet wide at the bottom, and 8 feet wide at the top. The detailed construction and bracing are shown in Plate 22. The plating varies in thickness from one-quarter inch to one-half inch. Referring to Plate 23, the manner of securing the wings to the pontoons will be seen. This is accomplished by means of a cast-steel shoe secured to the deck of the pontoon and connected by a link and taper wedge and similar shoe riveted to the side of the wing. On the outside of the dock, attachment to the pontoon is by a cast-steel strap through-bolted to the side of the pontoon. This device is of exceedingly simple construction and has proved most effective.

A pontoon has been detached by knocking out the wedges in less than ten minutes. The remainder of the dock is then pumped up, when the detached pontoons can be floated out and dry-docked on the remaining pontoons. The total weight of steel work in the wings is 1,100 tons. Attention is called to the fact that all of this steel is normally above the water-line, where it is accessible at all times for examination and repair.

Contact between the wings and pontoons is made by a raised packing piece, 12 inches wide, surrounding the open top of the pontoons under the wings, it being understood that there is a hole in the bottom of the wing to allow free passage of water from the pontoon to the wing when the pontoon is full. The joint between the pontoon and wing is made with three-ply canvas packing, saturated with red lead, and the wing, at the point of contact, is reinforced with $\frac{3}{8}$″ × 12″ steel plate to insure against possible corrosion, this being the only part of the wing, inside or out, which is not accessible when the dock is in commission.

By referring to Plate 20, showing a general plan of the dock, the method of pumping will be understood. This is by a centrifugal pump in each end of each pontoon, all the pumps on one side being operated by a single electric motor through horizontal line shaft and vertical shaft to the pump. The delivery and entrance of water to the pontoon is through the pump, which has been found to be a very effective method of control. A more complete description of the construction and operation of this dock can be found in "International Marine Engineering" under date of August, 1909.

While this dock is shown and referred to here as a 7,000-ton dock, with eleven pontoons and a length of 368 feet, it was actually built with ten pontoons and a length of 335 feet in the wings, this being the greatest length which would leave room for handling vessels in and out in its present location on the Company's property. The additional pontoon is to be added and the wings extended when the plant is enlarged.

Referring to Plate 24, there will be seen a general drawing of a 5,000-ton pontoon floating dry dock, in which both pontoons and wings are made of timber. While wooden wings are not practical for the largest size of docks, they are applicable to docks up to 10,000 tons.

It will be seen from the plans that there is a bulkhead in the wings corresponding to each pontoon and that the construction of the wings may be interrupted at any point. In order to extend the dock, it is only necessary to build one or more pontoons, float them in position and extend the wings over them, which can be done without interrupting the use of the dock.

The machinery and pumping of this dock is similar to the one previously described.

## COMPARISON OF WOOD AND STEEL FOR FLOATING DRY DOCKS AND METHODS FOR THEIR CARE AND PRESERVATION.

As previously stated, the building of timber floating dry docks in the United States is very old, and there are now in use in the Port of New York sixty-four floating dry docks, all of wood, ranging in tonnage from 400 to 12,000 tons, and in the United States there are ninety-one floating dry docks, three of steel and one with steel wings, ranging in tonnage from 200 tons to 18,000 tons, having a total tonnage of 228,800 tons and an average tonnage of 2,500 tons.

The only steel commercial floating dry dock is at the works of the Great Lakes Shipbuilding Co., Detroit, Mich. The only other steel floating dry docks in use in the United States are the Algiers dock opposite New Orleans, La., and the steel dock taken by the United States Government from Havana during the Spanish war, now in Pensacola, Fla. The Detroit dock and the Algiers dock are in fresh water, which makes their preservation much easier.

The Tietjen & Lang Dry Dock Co., of Hoboken, has nine floating dry docks, all of timber construction, varying in lifting capacity from 800 tons to 10,000 tons. Their first dock was built in 1884 and is still in satisfactory operating condition. No deterioration whatever has taken place in the timber work below water, but extensive repairs from time to time have

been made in the upper woodwork, which, of course, will deteriorate equal to, or somewhat more rapidly than, ordinary woodwork of buildings.

The John N. Robins Co., Erie Basin, Brooklyn, N. Y., has two large floating dry docks other than the pontoon dock with steel wings previously referred to. One of these docks, known as the Balance Dock, was built by William H. Webb and finished in October, 1854 (Plate 25), and has been in continuous use ever since. The writer has recently had the opportunity of thoroughly examining and overhauling this dock and changing over the pumping plant from steam to electric operation. A most thorough examination of the interior and weight-supporting timbers showed practically no deterioration, not a particle of decayed wood being found below the deck. Certain corrections were made, due to faults in the original design, to obtain a more positive control of the dock in operation, and since the overhauling the dock has lifted fully as heavy ships as at any time in its history. Much of the upper woodwork of this dock has been replaced and much more will have to be replaced from time to time.

Attention should be called to the fact that owing to the size of this structure, 330 feet long by 100 feet wide, it has never been possible to entirely remove it from the water.

The other large floating dry dock of the John N. Robins Co. is of the Dodge-Burgess type of sectional dock, having ten sections with pontoons 100 feet by 30 feet. The general construction of this dock can be seen by referring to Plate 26 and to the work by Stuart entitled "Naval Dry Docks of the United States," previously referred to, where there will be found excellent descriptions with illustrations of similar docks built for the United States Government at Philadelphia and Portsmouth, N. H.

In protecting the wooden pontoons of floating dry docks and, in fact, all under-water parts of floating dry docks, it has been the universal custom to first thoroughly grave them with brown tar poisoned with arsenic, then apply two layers of best sheathing felt, thoroughly graving each layer in a similar way, and then over this to sheath the dock with 1-inch creosoted hemlock boards well secured with galvanized nails. This has been found entirely satisfactory to protect these docks from toredo and worms and the custom in eastern waters has been to leave them in the water for seven years before taking them out to replace any sheathing which may have become detached.

The largest floating dry dock on the Pacific coast for many years was the Quartermaster's Dock in Puget Sound. This dock was built of timber in 1892, and while it has been exposed in what is considered to be very bad water for toredo since its construction, it was in excellent condition when

examined by the writer last winter, although on account of its dimensions it has never been removed from the water.

At the time of the construction of the pontoon dock with steel wings, a very thorough investigation was made as to the preservation of the steel wings by painting. This resulted in the use of a graphite paint of well known manufacture. The cleaning and painting was done in the most thorough manner by day's labor under skilled direction and when it was completed everyone expected the most satisfactory results. The outcome, however, was very disappointing. After two and a half years, the interior of the wings is now being coated with bitumastic composition and the outside will be painted with red lead and oil. None of the pontoons in the meantime have been removed from the water nor have they required attention in any manner.

All the writer's experience with floating dry docks and their construction and repair leads to the firm conclusion that for under-water work, such as pontoons for the Rennie type of dock, wood is a much superior material of construction to steel, that the original cost is much less, the cost of maintenance less, and the life of the structure greater than steel. For the wings and upper work, experience is equally conclusive for the use of steel. While it is apparent that the cost of maintenance will be considerable, the structure will last much longer, and, with a sectional pontoon dock where the wings are accessible at any time and any portion of the wings may be entirely replaced if necessary, it would seem that the structure as a whole will last indefinitely.

So far as the writer is able to judge by a somewhat limited experience, the only reliable protection for interior steel work of floating dry docks in salt water is the bitumastic compound above referred to, but the first cost of this protection is very great, being in the neighborhood of $6 per ton of steel for interior protection only. Any discussion which would bring to bear additional information upon this particular subject would be very much appreciated, and it is to be hoped that the experience of the United States Government with the floating dry dock Dewey at Manila will be of help.

A comparison of the materials used for wooden and steel pontoons shows that the weight of the steel per hundred tons of lifting power is 33 tons and the weight of wood per hundred tons of lifting power is 36 tons. It is evident that the difference in weight must be supplied by increased dimensions of the wooden pontoons. Other than in this particular, wood appears to have the advantage in every way.

While reference has been made to a pontoon dock of 7,000 tons lifting

capacity, there does not seem to be any engineering limit to the size to which the Rennie type of dock can be built with wooden pontoons. A carefully worked-out pontoon for a 20,000-ton dock shows dimensions of $130' \times 44' \times 15'$ and it will be readily understood that this structure is well within the practical limits for timber work.

Regarding the cost of the different types of floating dry docks, it is, of course, not possible to make any definite statements, as they are much influenced by the varying cost of material and the location where the dock is to be constructed. For the relative cost of the different types of docks on the eastern coast of the United States, the following figures may be taken as being approximately correct:—

COST PER TON OF LIFTING POWER.

| | |
|---|---|
| Balance sectional timber dock with centrifugal pumps | $32 per ton. |
| All wood pontoon dock with continuous wings..... | 35 per ton. |
| Pontoon dock, steel wings and wooden pontoons.... | 42 per ton. |
| All steel pontoon dock..... | 57 per ton. |
| Government steel dock, Dewey type..... | 62 per ton. |

The comparative cost for the western coast of the United States will be quite different on account of the increased cost of steel and the much lower cost of timber.

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## APPENDIX.

Through the kindness of the President, Mr. Stevenson Taylor, and by permission of Mr. James W. Folger, I am enabled to add to my paper the following which is of historic interest in relation to floating dry docks.

Referring to the accompanying picture, Plate 14, there will be seen one of the first floating dry docks, or, as it was then called a "Camel," which was built in the United States. The view shows Brant Point, Harbor of Nantucket, about 1842, when this "Camel" was built. It was used for entering vessels over the shoals in Nantucket Harbor until about 1850.

Additional information has been furnished by Mr. A. Milne, of Nantucket, Mass., as follows:

"The 'Camels' were each 135 feet long, had a depth of about 19 feet, a width of 29 feet on the bottom and 20 feet on deck, drew 10 feet 2 inches on a level and were connected by fifteen chains, five of $1\frac{1}{2}$ inches and ten of $1\frac{3}{8}$ inches which bore 800 tons weight. It required 200 tons to sink the 'Camels'

a foot into the water. Each 'Camel' was divided into two parts, a lower hold and between decks."

It is to be noted that the forward end of this floating dry dock is closed with a structure similar to a vessel's bow and it has been asserted that the name "Camel" originated from the fact that the first one of these sections was constructed from a vessel of that name.

NOTE.—The writer was in Seattle on March 6, 1911, and had the opportunity of examining the interior of the Heffernan Dry Dock, previously referred to in this paper, while carrying the steamer Victoria, 360 feet in length with a displacement of 5,000 tons. The dock was entirely pumped out, as this ship represented the maximum lift.

The examination extended through several compartments to the center bulkhead. All timbers were sound and there was no sign of deterioration from marine worms or any other cause.

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## DISCUSSION.

MR. HORACE H. THAYER, JR., *Member:*—Mr. Chairman, if it is in order, I would like to ask Mr. Donnelly what his idea is with regard to a composite pontoon.

MR. DONNELLY:—I have given the matter of composite construction considerable thought and study and have always found a great difficulty in obtaining a proper contact between the steel and wood members; that is, if the amount of steel is limited in direct proportion to its strength, I have found that the bearing contact with the wood is not sufficient to properly transmit the strain. In other words, a crushing action of the wood would take place.

Another difficulty, and perhaps the most serious, has been the greater tendency to rust at the contact of the steel and wood. This fact has been specially brought out in the experience of the John N. Robins Co. in repairing vessels, it being a usual experience to find the steel work under wooden decks very much corroded.

In designing the wooden pontoons and steel wings, particular attention was given to the matter of contact between the bottom of the wings and pontoons. To provide against possible corrosion of the wings an additional steel plate $\frac{3}{8}$ inch thick and 12 inches wide was added and, to eliminate the direct contact as far as possible with the wood, the joint was made with canvas and red lead, as referred to in the paper.

I am aware that there have been a number of composite floating dry docks built and would very much appreciate any contribution by the members having a definite knowledge of them.

CIVIL ENGINEER A. C. CUNNINGHAM, U. S. N. (Communicated):—In the combination of wooden sectional pontoons with steel side walls, Mr. Donnelly has secured a floating dry dock of comparatively low first cost, and moderate costs for maintenance and repairs. These are essential features in a commercial dock which, to be a success, must give a good return on the investment. A commercial dock must be out of commission as little as possible, and Mr. Donnelly's combination also tends to this condition. To prevent serious deterioration, a dock with

steel pontoons must be self-docked at reasonable intervals for cleaning and painting. With wooden pontoons these intervals can be much longer, as there is no rusting to contend with, and by keeping the wooden pontoons wet the rotting of the wood can be prevented. The steel side walls can always be preserved in place without disabling the dock.

The combination also permits of a dock of much greater capacity than in wood alone. The pontoons become merely beams for transmitting the weight to the side walls, and, when of steel, these can be designed and constructed to take any stress safely. There would probably be found a point where steel pontoons would be more economical than wood in first cost, but it would be considerably beyond the capacity of a purely wooden dock.

If a dock with wooden pontoons were located in waters where the toredo is plentiful and active, some attention would have to be given to the protection of the wood from the inside of the pontoon, especially if there were periods when the dock was inactive. The new graving dock at the Norfolk Navy Yard was flooded for several months before the caisson could be placed and the dock pumped out the oak keel blocks had been placed in the dock by the original contractor, and when the dock was pumped out it was found that the toredo had cut into the blocks about one inch. The greatest danger for the wooden pontoon would be at the bottom where there is always water, and this would also be the hardest place to inspect.

The link and wedge-pin connection between pontoons and side walls is extremely simple, rapid and effective. If made from steel they are presumably forged from the solid and have no weak point. By making them of soft steel and finally quenching in oil from a dark cherry-red, a metal with a high elastic limit and great toughness at the same time would be produced.

The preservation of the outside and inside of an all-steel floating dock, or of one with steel side walls only, is a matter of importance, and, with a commercial dock, a question of economy as well. The Government, in this country at least, has had the most experience in this matter. With the New Orleans dock in fresh water, and the Pensacola dock in salt water, a coal tar paint has been found to be the most enduring, as well as the least expensive preservative that could be applied to the outside. Red lead has not proven satisfactory on the inside of these docks and the coal tar paint is now being tried. The fumes from this paint are severe on the painter's eyes in a closed space, but this difficulty can be overcome by equipping the painter with a diver's or a fireman's smoke helmet.

Were it not for the impossibility of preserving and repairing the bottom, there are many who would prefer the solid dock to any self-docking type. In an effort to meet this case, the writer has proposed the use of a caisson, the general principles of which are shown in the accompanying sketch, Plate 27. The general proposition is not new, and to this class of appliances Mr. Lyonel Clark, the English floating dry-dock expert, has given the appropriate name of "limpet." The new feature in this caisson is the supplemental chamber shown in the sketch as having

a circular cross-section. The supplemental chamber gives increased control over the "limpet;" in sinking, the buoyancy of the combination can be first destroyed, thereby giving easy handling under water. The most important function of the supplemental chamber, however, is the insuring of a perfect seal against the bottom of the dock before the main chamber is pumped out.

When the revival in American shipping comes, the floating dry dock will immediately take a place of prominence and importance. Commercially it is an investment, the cost of which can be very closely estimated, and the time of completion of which can be accurately foretold, neither of which can be said of a graving dock.

MR. DONNELLY:—I should like to express my appreciation of Mr. Cunningham's contribution to the discussion, and in this connection would like to call attention to the fact that the difficulty with toredo in the basin dry dock to which he refers was probably due to the fact that the under-water structure was directly exposed to sunlight. In the examinations which I have made of the interiors of floating dry docks and pontoons I have never found any evidence of animal life. I consider this due to the fact that they were closed structures into which no light penetrated.

When the sectional dock referred to in the paper was repaired there was removed from the interior of the pontoons from one inch to eighteen inches of mud and silt and it was thought by some, in consequence of the presence of this material, that the bottom or lower timbers would be injured by worms or other marine life. Nothing of the kind, however, was discovered and, when cleaned out, the bottom and lower timbers were found to be in perfect condition. When it is understood that these pontoons had not been cleaned out in twenty years, the permanency of such a structure is quite apparent.

THE CHAIRMAN:—Is there any further discussion on this paper?

MR. THAYER:—Mr. Donnelly has asked for information upon composite docks. I do not know any detailed information except on one dock that I designed for the Government of Venezuela about five years ago; that cost fifty-five dollars per ton of lifting power, but it would not have cost as much as that if it had been erected in the United States.

MR. H. PENTON, *Member* (Communicated):—With regard to the question of maintenance of all iron or steel floating docks, I might say that when the floating dock of the Great Lakes Engineering Works, Detroit, referred to on page 62, was under consideration, the writer being at that time identified with that yard, the question of type and material was long and earnestly debated, the more so because we had less concern as to corrosion and maintenance than obtains in coast practise. In reaching a conclusion the longevity of the U. S. S. Wolverine, referred to in the Transactions for 1909, had a prominent part. We also had before us the

case of an iron floating dock in Spain, dating from, I believe, 1858, and still in apparently good condition, though not of the self-docking type. The question therefore resolved itself into one of almost negligible maintenance as to steel on the one hand as contrasted with comparatively short life and continually advancing prices of wood as used in dock construction, on the other. The question of excavation was largely eliminated because of the side-launching method prevailing on the lakes, and with which the members are familiar, enabling the use of the same slip for both dry dock and launching berths. In fact, it is a common practise to launch even the largest ships, up to 600 feet in length and 60 feet beam, sidewise into the ordinary basin dock having a top width of about 100 feet.

At that time, 1902, there were on the lakes only four ships of 500 feet in length and the tendency seemed to be toward a somewhat shorter ship. We therefore decided that a length of 450 feet was all that we were warranted in providing for, and we accordingly fixed up the sectional sea-docking type consisting of three sections, each approximately 150 feet in length, to which a fourth section was added later. In fact, before the three sections as originally planned were built, we ourselves were building ships of considerably over 500 feet in length.

Still later, to provide extra flexibility, two other shorter sections were built. The Ecorse dock is, therefore, so far as my information goes, the largest floating dock in the world in respect of linear dimensions, though not as to lifting capacity. The latter is not an important requirement in mercantile work because underwriter's restrictions prohibit docking a loaded vessel except at owner's risk. So far as relative endurance of wood and steel is concerned, at least in fresh water, the life of a steel or iron dock is entirely unknown, while that of a wooden basin or floating dock is fairly well established.

MR. DONNELLY:—Replying to Mr. Penton's discussion, I would say that the very slight action of fresh water upon iron and steel has been thoroughly established, and it is practically certain that for fresh water very little deterioration in steel structures need be anticipated. In fact, very few vessels on the Great Lakes are painted on the outside below the water-line, and this fact in itself divides, by more than one-half, the necessity for dry docks in fresh water.

CIVIL ENGINEER LEONARD M. COX, U. S. N., *Associate* (Communicated):—The writer is particularly interested in Mr. Donnelly's timely paper owing to the fact that he was closely associated (as an observer only) with the timber-steel Robins dock throughout the period of construction and test, having been designated by the Navy Department, on Mr. Donnelly's invitation, to visit the dock as often as necessary and to report in detail upon the type. It is a privilege to discuss a paper which describes a real advance in the development of any particular type of structure, and it must be apparent that the design of the Robins dock marks a very definite step forward.

Speaking broadly, the life of a modern self-docking steel floating dock should,

if the structure is properly cared for, be of practically indefinite duration. It is equally true that old fashioned "quick consumption" is not more rapid in its ravages than the deterioration of a steel dock if it fails to receive proper "medical" attention. This attention is expensive and the demand for it is constant. The United States Government has had experience with only three docks of this type, the oldest having been in service only eight years. Data based upon even this meager experience would be of great value, but are impossible to obtain owing to the unfortunate system of accounting which, while accurate as to funds expended and well adapted to the business needs of the Department, is of little value to the professional man, in that it offers no way to differentiate accurately between repairs and structural maintenance charges, and charges due to operation or operating maintenance.

Lyonel Clark, the noted English designer, has given about the only published data on maintenance cost* with which the writer is familiar. From these data, derived from experience with eight docks designed by him, the maintenance cost should run from .7 to 1.7 of 1 per cent. of the first cost annually. Mr. Clark assumes a life of fifty years for his structure, on the prediction that any type of dock will become obsolete during such a period. On this assumption he proposes the establishment of a 1 per cent. sinking fund to charge off the cost of the structure at the termination of its usefulness. Had we an appreciable merchant marine, anything approaching the above figures would certainly not make a bad showing as a commercial proposition.

While experience with our own naval docks may not as yet confirm or disaffirm Mr. Clark's estimates of annual maintenance cost, we are in position to state very definitely just what parts of a steel floating dock are most liable to deterioration and the most difficult to protect. It may be said that the side walls or towers above the light draught line are practically immune from any but weathering effects and general wear and tear. The outside skin plating shows comparatively little deterioration and it is even a matter of doubt if the covering of marine growths collected in most waters does not afford better protection than frequent self-docking, scraping and painting. The pontoon deck on a large dock causes considerable trouble owing to the fact that the plates are never true planes, and the numerous little hollows hold pools of water. This starts rust under any paint so far tried. It will be seen, therefore, that the outside of a steel dock does not suffer extraordinary deterioration and is comparatively easily cared for, but, on the other hand, the inside—and in particular the inside of pontoons—presents an entirely different set of conditions. Continually wet, inaccessible, dark, filled with stagnant air, it is almost impossible to paint them properly, corrosion takes place at a rapid rate, and everlasting trouble and difficulty, to say nothing of expense, is the logical result. It may not be an exaggeration to assert that nine-tenths of the entire deterioration, and the same proportion of upkeep charges,

*Proc. Inst. C. E., Vol. CLXI, session 1904–5, part III.

do or should originate in the interior of pontoons. It has been said that nine-tenths of man's trouble is due to his stomach and—to press the analogy further—the interior of pontoons can be no more easily dispensed with.

Mr. Donnelly has solved the problem, within the limits of his material, by building his towers of steel and his pontoons of timber. His pontoons are immune from corrosion and may be protected on the outside from the toredo, while conditions on the inside do not favor the best work of that pest. As a commercial proposition it would seem that the "Donnelly type" satisfies the long search for a dock combining the advantages of a steel structure with moderate first cost and reasonable upkeep charges.

For naval purposes it is doubtful if this type will ever be adopted for the larger class of ships. This for the reason that naval architects give the first desideratum for warship docks as extreme stiffness. The warship is a delicate structure and should be docked on a level, and as nearly non-flexible, platform as possible. This requirement necessitates the closest approach to a solid trough dock as is compatible with the necessary self-docking features, and virtually eliminates all types consisting of numerous short pontoon sections with separate side walls. On the other hand the construction of a one-piece 35,000-ton timber floating dock is obviously beyond the practical limits of timber construction.

For the smaller class of naval vessels, such as torpedo boats, destroyers, gunboats and smaller cruisers, the combination structure offers a most satisfactory facility and there is need for quite a number of such docks at the present time. It might be well if every repair station were equipped with at least one small dock of, say, 3,000 tons lifting capacity, for use as a relief for the larger graving docks—a step that would be warranted from motives of economy as well as of strategy.

A recent report on the condition of the floating dock Dewey discloses a considerable amount of deterioration of all exposed metal in the interior of pontoons, except that part covered by bitumastic enamel, which was found to be apparently unchanged. Bitumastic was placed hot, $\frac{1}{8}$ inch thick, over all plates, shapes and other metal, on the floors of pontoons and for a height of 12 inches upward on the vertical surfaces. All other interior surfaces were covered with three coats of red lead. The cost of applying bitumastic was in the neighborhood of seven cents per square foot of surface covered. It may be of interest in this connection to state that experience with the bitumastic solution alone has been unsatisfactory in locations where it has been tried, and the enamel, when placed on the outside of floating structures, has proven equally unsatisfactory. Red lead and certain brands of graphite paints have given the best service on exposed surfaces on the outside of the structure and inside of side walls, except on decks. No satisfactory protection for decks has yet been discovered but, of all those yet tried, the Cunningham tar paint has given the best results, and it is probable that entire satisfaction might be obtained from this covering when better and more uniform methods of applying it have been determined.

The limits of this discussion do not permit specific mention of all the valuable

features of the particular dock designed by Mr. Donnelly for the John M. Robins Co., but the ingenious flooding and pumping arrangement is especially worthy of commendation. The writer was present at the official docking test and testifies to the splendid working of every part in sinking and in raising. At all times the trim was under perfect control and an inexperienced dock master might have conducted the operation with perfect safety. The same praise applies to every detail of the Robins shipyard, which has been rearranged for electric power throughout, in accordance with Mr. Donnelly's design.

The table "Cost per Ton of Lifting Power" on page 65 of the paper is a most interesting one, but inasmuch as the government dock Dewey was designed with 10,000 pounds unit stress instead of 12,000 as used for the "All Steel Pontoon Dock," it is apt to produce a slightly erroneous impression in the minds of those prone to criticise government methods. The difference in unit stresses allowed in each case eliminates at least a portion of the difference in per ton costs and the remainder of this difference is accounted for by the peculiar requirements of the naval service.

THE CHAIRMAN:—Anything further, gentlemen? If not, we will pass this paper and I am quite sure I express your opinion when I say Mr. Donnelly is entitled to your thanks for a most interesting paper.

"Our Constitutional Shipping Policy and the Compact for its Establishment," by Mr. William W. Bates, Member, is our next paper. It will be read by the grandson of the author.

THE SECRETARY:—Mr. President, I would like to state, in regard to Mr. Bates' paper, that he wrote saying he could not read it himself, and requested that his grandson read the paper.

It was moved, seconded and carried unanimously that the paper be read and incorporated in the proceedings.

# OUR CONSTITUTIONAL SHIPPING POLICY AND THE COMPACT FOR ITS ESTABLISHMENT.

By William W. Bates, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

To understand our subject well, we need to study pertinent historical facts preceding, during, and following the Revolution. When it appeared that a struggle for freedom from kingly oppression was imminent, the colonies organized a general government such as seemed necessary to collect and direct the resisting energies of the people. Only a loose confederacy was intended. "Articles of Confederation"—as few as possible—comprised the authority of Congress. Congress could plan for defense, but the men and money for execution were to be furnished by the several states. At first this was done as required, afterwards at convenience or not at all.

Congress could not legislate concerning commerce or navigation, lay a tax or collect a duty, regulate the currency or encourage industries. These things were attended to by each state for itself. The general authority was much impaired toward the end of the war. The states then furnished but scanty means for carrying it on. After its close, with disunion in sight, it was even more clearly seen than ever that, on the ground of safety alone, the Union should be continued. Without a general government making for nationality, our dearly bought independence was insecure; foreign intercourse would be restricted and difficult; domestic commerce, under different state regulations, caused friction which might result in warfare; safety of life and property and freedom depended on peace and tranquillity. Prosperity would not obtain unless a stable and energetic government, on the republican plan, cared for and encouraged the development of natural resources. Particularly must commerce and navigation and the fisheries be promoted and sea power obtained.

Unless a national government of a closer union, under a wise constitution, were soon established, America, instead of becoming a single, strong nation, its freedom secure, its prosperity favored by good conditions, its power developing with population, a dissolution of the existing union would certainly take place, and in time be followed by two or more confederacies; or, the several states remaining single, each might make foreign alliances; or some be reduced to dependencies of foreign nations, thus encumbering the continent with fortifications, standing armies, dis-

cordant governments, highly taxed and impoverished people—after the example of Europe. Great Britain was then neglecting to observe the treaty of peace. She was determined, and already preparing, to engross our commerce and navigation—that no rival should rise in the west. By a proclamation of her king, the ports of the British West Indies and of the loyal provinces were shut to the vessels of the United States. All intercourse was reserved for British vessels. We were prohibited the carrying of our own exports. This action was a violation of international shipping rights. England had refused to make a commercial treaty. This refusal has been said to have given us our Constitution. Certainly, the king unwittingly put renewed life into the Congress of the time. Several states called its attention to his encroachment, and a committee headed by Thomas Jefferson reported that improvement of conditions could only come from "navigation laws" such as would counteract foreign regulations and protect the vessels of the several states. The states should be requested to confer on Congress, for fifteen years, authority to enact such regulations of commerce as might seem essential to the end in view. For various reasons the states did not respond as desired. Seeing the failure of the proposition, each state, for itself, enacted navigation laws. These were quite diverse—discriminating tonnage duties in one state, discriminating tariff duties in another, and both kinds of duties high in a third state. Unfortunately, the regulations of one state applied to the vessels and cargoes of the others, just as they did to those of foreign countries—the vessels of the several states being foreign in all states not their own. Little protection against foreign vessels resulted, while much friction followed between the states, mitigated somewhat by reciprocity agreements.

Thus it was demonstrated that only "uniform" regulations of commerce, enforced by a national government against foreign vessels only, would answer the purpose of building up an American marine—the only basis for commercial independence and strength on the ocean. The weaker side of our country was toward the ocean. From that side had already come the first invasion of our rights. We might expect more aggression from the same quarter. The remedy for our sea-weakness would only be found in shipping and commercial prestige—the growth of the marine, the building of vessels and the extension of commerce by the hands of our own people. Our situation with respect to the sea was well described by Judge Jay, of New York:—

"Among the many objects to which a wise and free people find it necessary to direct their attention, that of providing for their safety seems to be the first. * * * But the safety of the people of America against

dangers from foreign force depends not only on their forbearing to give just causes of war to other nations, but also on their placing and continuing themselves in such a situation as not to invite hostility or insult; for it need not be observed that there are pretended as well as just causes of war. * * *

"With France and with Britain we are rivals in the fisheries, and can supply their markets cheaper than they can themselves, notwithstanding any efforts to prevent it by bounties on their own, or duties on foreign fish. (1787.)

"With them, and with most other European nations, we are rivals in navigation and the carrying trade; and we shall deceive ourselves if we suppose that any of them will rejoice to see it flourish; for, as our carrying trade cannot increase without in some degree diminishing theirs, it is more their interest, and will be more their policy, to restrain than to promote it."

The press of the time teemed with matter on the state of the Union and the prospect of advancement under independent government. The importance of the Union, in a commercial point of view, was one of the few topics on which all writers seemed agreed. Shipbuilding, navigation and commerce must be leading trades of America. Alexander Hamilton, of New York, wrote as follows:—

"There are appearances to authorize a supposition that the adventurous spirit which distinguishes the commercial character of America has already excited uneasy sensations in several of the maritime powers of Europe. They seem to be apprehensive of our too great interference in that carrying trade which is the support of their navigation and the foundation of their naval strength. * * * They foresee the dangers that may threaten their American dominions from the neighborhood of states which have all the dispositions, and would possess all the means, requisite to the creation of a powerful marine. Impressions of this kind will naturally indicate the policy of fostering divisions among us, and of depriving us, as far as possible, of an active commerce in our own bottoms. This would answer the threefold purpose of preventing our interference in their navigation, of monopolizing the profits of our trade, and of clipping the wings by which we might soar to a dangerous greatness."

For the purpose of accomplishing the best results of enterprise and industry, every patriot believed with General Washington in the advantages of a government "competent to assert and maintain every right of the people."

According to the judgment of Alexander Hamilton:—

"Under a vigorous national government, the natural strength and resources of the country, directed to a common interest, would baffle all the combinations of European jealousy to restrain our growth. This situation would even take away the motive to such combinations, by inducing an impracticability of success. An active commerce, an extensive navigation and a flourishing marine would then be the inevitable offspring of moral and physical necessity. We might defy the little arts of little politicians to control, or vary, the irresistible and unchangeable course of nature.

"But in a state of disunion, these combinations might exist and might operate with success. It would be in the power of maritime nations, availing themselves of our universal impotence, to prescribe the conditions of our political existence; and as they have a common interest in being our carriers, and still more in preventing our becoming theirs, they would, in all probability, combine to embarrass our navigation in such a manner as would in effect destroy it, and confine us to a passive commerce. We should thus be compelled to content ourselves with the first price of our commodities, and to see the profits of our trade snatched from us to enrich our enemies and persecutors. That unequalled spirit of enterprise which signalizes the genius of the American merchants and navigators, and which is in itself an inexhaustible mine of national wealth, would be stifled and lost; and poverty and disgrace would overspread a country which, with wisdom, might make herself the admiration and envy of the world."

Alluding to the defects of the general government then existing, and to its unfitness for the administration of the affairs of the country, Mr. Hamilton declared that several "powers" were lacking.

"The want of a power to regulate commerce is by all parties allowed to be of the number. The utility of such a power has been anticipated under the first head of our inquiries; and for this reason, as well as from the universal conviction entertained upon the subject, little need be added in this place. It is indeed evident, on the most superficial view, that there is no object, either as it respects the interests of trade or finance, that more strongly demands a Federal superintendence. The want of it has already operated as a bar to the formation of beneficial treaties with foreign powers, and has given occasions of dissatisfaction between the states."

It might be said of the discussions of the time that the preservation of the Union, coupled with the "regulation of commerce," foreign and domestic, was an idea often and generally expressed. James Madison, of Virginia, afterwards styled "the father of the Constitution," wrote thus:—

"Every man who loves peace, every man who loves his country, every man who loves liberty, ought to have it ever before his eyes, that he may

cherish in his heart a due attachment to the Union of America, and be able to set a due value on the means of preserving it. * * * It must indeed be numbered among the greatest blessings of America that, as her Union will be the only source of her maritime strength, so this will be a principal source of her security against danger from abroad. * * *

"The defect of power in the existing Confederacy to regulate the commerce between its several members is in the number of those which have been pointed out by experience. * * * Without this supplemental provision, the great and essential power of regulating foreign commerce would be incomplete and ineffectual."

In 1787 a National Convention, composed of delegates from all the states except Rhode Island, met, considered and completed the Federal Constitution. The only discussion of the power to "regulate commerce" was in connection with its use for the encouragement of the merchant marine, in which the question was on a resolution that bills for "navigation laws" should receive a "two-thirds vote." This was decided in the negative, and the necessary clause was afterwards agreed to unanimously.

As near perfection as it was, the new Constitution had much opposition in the public press. Hamilton and Madison, both members of the Convention, were the most distinguished writers in its explanation and defense. Concerning the power to regulate commerce, Mr. Madison wrote:—

"If the new Constitution be examined with accuracy and candor, it will be found that the change which it proposes consists much less in the addition of new powers to the Union than in the invigoration of the original powers. The regulation of commerce, it is true, is a new power, but that seems to be an addition which few oppose, and from which no apprehensions are entertained."

It should be understood that all the powers of the Constitution are derived from the states, and were given up by them and taken over by the Federal Government, not for ornament or to be laid aside, but for actual use—for the advantage and benefit of the nation forever. The powers of government not essential to national administration remain with the states. They refused to give up any power not thus essential. In the nature of the case, every power given up was transferred on condition and promise of its faithful exercise. The Federal Government had no moral right to receive, on any condition, any power whatever that it did not intend to exercise; and only in bad faith can it relegate any power to desuetude. The "suspension" of ship protection, or of any other promise, is a violation of compact.

It seems to be supposed by many that Congress may enact laws regard-

less of the Constitution, and that this charter, given by the states and the people, cuts little figure at Washington. But this is a sad mistake. That we have a constitutional shipping policy extant to-day is no wonder at all. The several states, as we have seen, had a policy of trade regulations, and thought it vital to their commercial independence. They turned this policy over to the United States, the only object being to increase its efficiency, and to get a great nation to enforce it forever. From the debates in the Convention it is clear and positive that the shipping policy of the states was to become that of the United States, and that this was one of the "bonds and conditions" of the Union—just as much as allowing each state, big or little, two Senators in Congress, or that provision reserving certain rights to the states, or that concerning the President's nativity, or that limiting his term of office—just as much, in fact, as any provision of a fundamental character.

Let us glance at the debate in the Convention. General Pinckney, of South Carolina, offered and advocated a resolution that a "two-thirds vote" should be required for the passage of a "navigation act."

Mr. Clymer, of Pennsylvania, said:—"Difficulties ought not to be increased by unnecessary restrictions. The northern and middle states will be ruined if not enabled to defend themselves against foreign regulations."

Governor Morris, of Pennsylvania, declared that "preferences to American ships will multiply them till they can carry the southern produce cheaper than it is now carried. A navy was essential to security, particularly of the southern states, and can only be had by a 'navigation act' encouraging American bottoms and seamen."

Mr. Williamson, of North Carolina, thought "the restriction would please the southern people."

Mr. Spaight, of Virginia, opposed the motion—"The southern states could at any time build ships for their own use." (Charleston and Baltimore were then shipbuilding ports.)

Mr. Butler, of South Carolina, also opposed the motion, while Mr. Mason of Virginia supported it.

Mr. Wilson, of Pennsylvania, thought "if every peculiar interest was to be served, unanimity ought to be required."

Mr. Madison, of Virginia, went fully into the subject:—"The disadvantage of the southern states from a 'navigation act' lay chiefly in a temporary rise of freight, attended, however, with an increase of southern as well as northern shipping, with the emigration of northern seamen and merchants to the southern states, and with a removal of the existing and injurious retaliation among the states on each other. The power of foreign

nations to obstruct our retaliatory measures on them, by a corrupt influence, would also be less if a majority should be made competent to legislative acts in this case. An abuse of the power would be qualified with all these good effects. But," he thought, "an abuse was rendered improbable by the provision of two branches; by the independence of the Senate; by the negative of the President; by the interest of Connecticut and New Jersey, which were agricultural, not commercial, states; by the interior interest, which was also agricultural; by the accession of western states, which would be altogether agricultural. The southern states would derive an essential advantage in the general security afforded by the increase of our maritime strength."

Mr. Gorham, of Massachusetts, speaking for New England, said:—"If the Government is to be so fettered as to be unable to relieve the eastern states, what motive can they have to join it and thereby tie their own hands from measures which they might otherwise take for themselves? The eastern states were not led to strengthen the Union by fear for their own safety. He deprecated the consequences of disunion, but if it should take place it was the southern part of the continent that had the most reason to dread them. He urged the improbability of a combination against the interest of the southern states, the different situations of the northern and middle states being a security against it. It was, moreover, certain that foreign ships would never be altogether excluded, especially those of nations in treaty with us."

Thus was the fact disclosed to the Convention that the encouragement of the merchant marine, free of restrictions, was an indispensable requisite for a permanent union of the states. Had this matter been settled otherwise, New England, New York, Pennsylvania and Virginia would not have adopted the Constitution. This being clearly seen, the grant of power was made "nem. con." No provision of the Constitution contributed more to its adoption. No power exercised by Congress ever created so much prestige and advantage for our republic. Our early marine was, verily, "the Child of Protection." This statement will not be contradicted and need not be proved. Nor need further evidence be given to show that the mode of this protection—and its original power—was given up by the states and taken over by the General Government, on condition that the protection desired and necessary should always be afforded. By this compact the states were relieved of their natural duty to encourage and protect a most important industry, and the United States, by virtue of it, promised and undertook the duty, with no right reserved ever to discontinue it.

Nevertheless, this solemn compact was violated by Congress. At the height of our marine prosperity, in 1826, when our vessels were carrying 95 per cent. of imports and 89.6 per cent. of exports in our own commerce, the President recommended the "suspension" of ship protection in the foreign trade. The measure passed in 1828. "Maritime Reciprocity"—free and open trade with favored nations—was the fad. Foreign nations could call for this advantage at convenience and enter into "convention" for a term of years—usually ten, each party reserving the right to terminate it afterwards by giving a year's notice. Conventions averaged one each year. By 1860, thirty nations had taken advantage of our Act of May 24, 1828, and our shipping decline was well under way—thanks to mistaken theory.

### THE ACT THAT HAS DESTROYED OUR MARINE.

"That upon satisfactory evidence being given to the President of the United States, by the government of any foreign nation, that no discriminating duties of tonnage or impost are imposed or levied in the ports of said nation upon vessels wholly belonging to citizens of the United States, or upon the produce, manufactures or merchandise imported in the same from the United States, or from any foreign country, the President is hereby authorized to issue his proclamation declaring that the foreign discriminating duties of tonnage and impost within the United States are and shall be suspended and discontinued so far as respects the vessels of the said foreign nation, and the produce, manufactures and merchandise imported into the United States in the same from the said foreign nation, or from any other country; the said suspension to take effect from the time of such notification being given to the President of the United States, and to continue so long as the reciprocal exemption of vessels belonging to citizens of the United States and their cargoes, as aforesaid, shall be continued, and no longer."

There was no reason of state for this act. No nation was demanding it. Under its operation for the past forty-five years, with scarcely any protection, our foreign-trade marine has almost disappeared. No merchant vessels belong to the "United States," save as vessels built and owned in different states of the Union—registered under the laws of Congress. The many who have been, and the very few that are yet, engaged in the building and running of our foreign-trade marine are now in this situation: The different states cannot, as formerly, protect their shipping; and the Federal Government has "suspended" its law for so doing. More than this, Congress has no other way to relieve the situation than to terminate

our shipping conventions and to resume vessel encouragement where it was thrown off, beginning in 1828. In other words, the Federal Government has no other course than to resume the observance of the compact and policy of the Union and the Constitution.

In the first place, the Act of 1828 was an abuse of power, without authority, void and destructive. The authority of Congress under the Constitution is a delegated authority, to be used lawfully and beneficially—not otherwise. Alexander Hamilton, in advocating the adoption of the Constitution—and but for his learning and eloquence New York would have rejected it—made this assertion:—

"There is no position which depends on clearer principles than that every act of a delegated authority, contrary to the tenor of the commission under which it is exercised, is void. No legislative act, therefore, contrary to the Constitution, can be valid. To deny this would be to affirm that the deputy is greater than his principal; that the servant is above his master; that the representatives of the people are superior to the people themselves; that men, acting by virtue of powers, may do, not only what their powers do not authorize, but what they forbid."

The compact with the states, as such, and also with the people, made by the Convention, was for "navigation laws," to encourage and upbuild the merchant marine and the foreign carrying trade, not to perish and destroy these trades by the constant operation of a faithless act for unprotection. Moreover, to clinch the argument, the Constitution having provided for a specific method of encouragement and protection (that of trade regulations, meaning "discriminating duties of tonnage and impost"), all other methods are thereby precluded; while there is no authority for the taxation that would be necessary for the fostering of the marine by subsidizing, were that method adopted.

That other nations have power to subsidize their vessels, but we have not—this power remaining in the states—is not surprising. Rather, the wonder is that some of us do not better understand the principles and the limitations of our National Government. What is wanting and is demandable is an honest observance of the compact for "navigation laws," on the lines of those now "suspended" in the interest of foreign nations, costing nothing but governmental good faith, to produce satisfactory results.

In conclusion, let no one say that insuperable obstacles exist, for any difficulties are of our own making, and the right was reserved to retrace our steps. The welfare of the country demands the carrying out of the compact for "navigation laws," and our National Government is perfectly able to resume that policy. We pretend to be an independent nation, but a mari-

time nation without a marine of its own for its own foreign trade—its commerce "passive"—is not an independent power. Once we were potent on the ocean, and led the world in navigation. Now inferiority, subordination, dependency, are words descriptive of our status. Our unprotective policy is blamable for this. So are the statesmen who continue it.

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## DISCUSSION.

THE CHAIRMAN:—There is nothing further for us to consider this afternoon, only I again remind you of the banquet and also remind you of commencing early to-morrow morning and sticking to the five-minute rule in discussion. The meeting stands adjourned until to-morrow morning at 10 o'clock.

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### FRIDAY, NOVEMBER 18, 1910.

Members began to assemble at 10 A. M., pursuant to adjournment.
The President took the chair and called the meeting to order at 10.30 A. M.

THE CHAIRMAN:—I am very gald to see, gentlemen, that the arduous discussions of yesterday did not tire you all out, and that you are here to resume the papers of to-day. We would have started promptly at ten o'clock, had it not been for a very important meeting of the Council which had to be held at that time.

The first paper this morning is "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for Their Construction," by Professor William Hovgaard, Member. I am happy to say Professor Hovgaard still lives, in spite of reports to the contrary.

# AN ANALYSIS OF TESTS OF WATER-TIGHT BULKHEADS WITH PRACTICAL RULES AND TABLES FOR THEIR CONSTRUCTION.

By Professor William Hovgaard, Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

This paper is a continuation of last year's paper on the "Strength of Water-tight Bulkheads." While that paper was of a purely theoretical nature, the present paper contains an analysis of bulkhead tests, followed by practical rules and tables based on this analysis.

The majority of tests here recorded and analyzed, in fact all except the last two, have been carried out in American battleships and cruisers. Probably no other navy has undertaken so great a number of scientifically conducted tests as the United States Navy, and it is at least certain that no other navy has been so generous as to permit a publication of the results. As far as the author is aware, no reliable and exhaustive information on bulkhead tests had been published anywhere prior to 1898, when the late, eminent Naval Constructor J. J. Woodward, U. S. Navy, published his valuable paper on this subject in the Transactions of this Society, and very little has come to light since that time. The careful and scientific methods in carrying out the tests, which were originated by Mr. Woodward, have been used ever since in the United States Navy.

During the present analysis new theoretical problems have occurred, and improved methods of solution of problems, already discussed, have suggested themselves in some cases. This paper shall therefore begin with an extension of the theoretical treatment given in last year's paper.

## I. Further Development of the Theory.

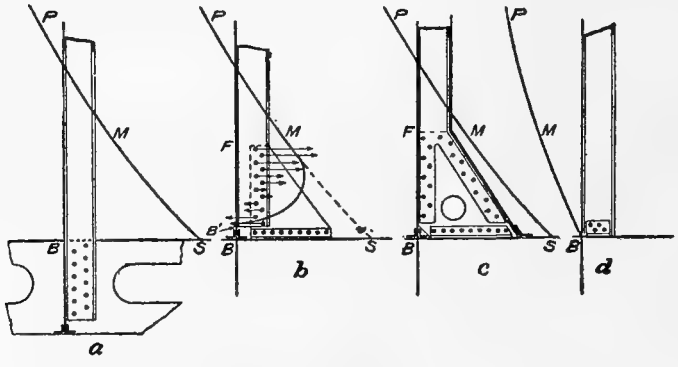
### *a.* Brackets.

In last year's paper the effect of a bracket was considered equivalent to a bending moment exerted at the end of the stiffener, and the stiffener was regarded as carrying this bending moment without being structurally reinforced by the bracket. This is the ordinary theoretical view of the case, but is correct only if the bracketing is effected by extending the stiffener down below the top of the floors, connecting it to a floor plate or longitudinal as indicated in Fig. 1, *a*, and provided we consider the stiffener

to end at $B$ and to be strictly vertical at this point. The stiffener is then at $B$ subject to the entire bending moment $BS$ without any reinforcement in strength at this point.

FIG. 1.

M INDICATES CURVE OF BENDING MOMENTS.




We shall now consider the more ordinary case where a triangular bracket is fitted, and we shall assume that the main bar of the stiffener is held so that its end is strictly vertical, *i. e.*, so that perfect encastrement is attained, and that the structural element of the hull, to which the bracket is attached, is perfectly rigid. We must here take account of the facts, firstly, that the supporting forces exerted by the bracket are applied at some distance from the end of the bar, and, secondly, that when the bracket is intimately connected with the stiffener, it serves to reinforce the stiffener structurally by increasing its moment of inertia.

Let us consider separately the two forms of brackets illustrated on Fig. 1, *b* and *c*.

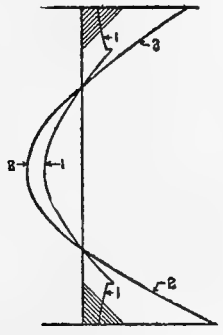
The bracket shown on Fig. 1, *b*, may be considered to be quite independent of the bar of the stiffener, *i. e.*, as a more or less rigid fixture to which the bar is connected, but which does not reinforce it. The effective height of the bracket is in this case not $FB$ but $FB'$, the overlap of the bracket on the bar, since no increase in the height of the bracket would increase its hold on the stiffener as long as this overlap remains the same. Evidently there can be no bending moment at the end of the stiffener or even at the lowest rivet. The supporting force, instead of being applied at the end of the stiffener, as generally assumed in the theoretical treatment of this problem, is actually subdivided in minor forces, applied at the various rivets on the overlap, and these forces will greatly affect the bending moments to which the stiffener proper is subject between $F$ and $B'$. Referring to Fig. 1, *b*, the curve of bending moments, instead of being continued to the point $S$, as generally assumed, will reach a maximum a little below

the apex of the bracket and will go to the zero point at the lowest rivet on the overlap of the bracket. The maximum bending moment thus found on the overlap will probably not be much greater than that at the middle of the stiffener, but the shearing forces acting on the upper rivets of the bracket must be very great.

By the second form of bracket, Fig. 1, *c*, the bar of the stiffener is split and intimately connected to the bracket, or some other form of equally efficient connection is used, so that the bracket may be regarded as forming an integral part of the stiffener. We need not in this case consider the action of individual rivets; the stiffener carries the entire bending moment *BS* at the end, as given by the curve *PS*, but being reinforced by the bracket, the stresses will, with a well constructed bracket, not be as great as at the apex of the bracket. Fig. 2 gives the curve of stress for a stiffener bracketed as in Fig. 1, *c*.

FIG. 2.

1. CURVE OF STRESSES.
2. CURVE OF MOMENTS.



Hence by this form of bracket, being more certain in its action than the bracket shown in Fig. 1, *b*, we are only concerned with the free part of the stiffener between the brackets, and it must be of advantage to make these of such a height that the bending moments occurring at the apex of the brackets, *C* and *D* in Fig. 3, shall be not greater than the maximum which is found near the middle of the stiffener at *O*. The result of this requirement is shown in Fig. 3, where the height of brackets, *BD* and *AC*, required for its fulfilment is given in the different cases of bracketing.

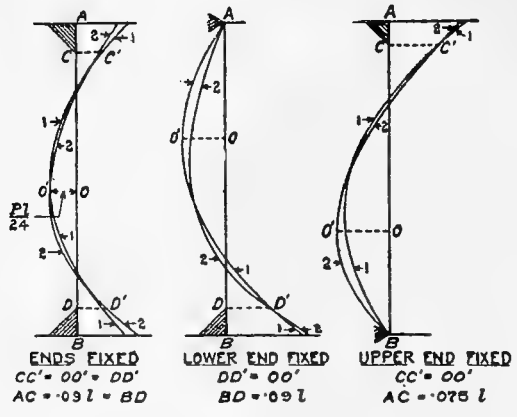
Curves of bending moment are shown both for uniform and for increasing (triangular) load. For a partly uniform, partly increasing load the curve would be intermediate between those given on the figure.

FIG. 3.

CURVES OF BENDING MOMENTS.

1. UNIFORM LOAD $P_1$ 2. TRIANGULAR LOAD $P_2$

$P_1 = P_2$




As seen from the diagrams, equalization of the moments at *C* and *D* with that at *O* is attained in all cases, when the brackets are of a height equal to somewhat less than one-tenth of the length of the stiffener.

It is clear, however, that the height of the brackets must be regulated not only by the length but also by the strength of the stiffener. In case of deck beams the same problem occurs, and practise has there fixed upon a depth of knee or bracket of about three times the depth of the beam. The same rule may be applied to the lower brackets of stiffeners, provided that the bar is split and that its free flange with face plate or reversed bar, if any, is carried out along the sloping (outstanding) edge of the bracket.

The horizontal side of the bracket should likewise be of a length equal to about three times the depth of the stiffener.

The length of the sides of the upper bracket in a stiffener, which is bracketed also at the foot, may be about ten per cent. less than in the lower bracket.

Referring to last year's paper, it was stated on page 391 of the Transactions (1909) that when a stiffener is bracketed at the foot and freely supported at the top, the maximum bending moment will be greater than if the stiffener had been freely supported at both ends. This statement requires qualification, for, as explained above, it is true only if the bracketing is effected by connecting the stiffener to an absolutely rigid floor plate or longitudinal as shown in Fig. 1, *a*, instead of simply attaching it to the top of the floors as in Fig. 1, *d*. It is not true if an effective bracket is fitted above the floors as in Fig. 1, *b* and *c*.

In Table II of the Report of the British Bulkhead Committee of 1890

no distinction is made between these cases (Fig. 1, *a* and Fig. 1, *b* or *c*), since the same sizes of bars are recommended whether the bars are "efficiently connected to the intercostals between the floors in vessels having ordinary floors," or whether they are "secured with efficient brackets to the inner bottom in vessels having cellular bottoms."

In case of stiffeners supported at both ends and at an intermediate point the statements made in last year's paper (see the Transactions, 1909, page 393), concerning bracketing of a stiffener, which is continuous over the middle point of support, should, in the light of the above discussion on brackets, be amended to read, that the best solution is obtained by bracketing at all three points and not only at the ends, since the stiffener will thus be reinforced at the middle point where a great bending moment is found. If only one bracket is fitted at the middle point, it should be fitted below rather than above this point.

### *b.* FORMULAS FOR THE CASE WHEN THE LEVEL OF THE WATER IS BELOW THE TOP OF THE STIFFENER.

This case was omitted in last year's paper, but as it occurs in the present analysis, and as it may occur in many other cases, the solution is given in the Appendix.

### *c.* FORMULAS FOR TENSION AND BENDING COMBINED.

The solution of this problem given in last year's paper may be much simplified in cases where the maximum elastic deflection, $\delta$, of a stiffener is known, as in case of the analysis of a given test. As shown in the Appendix, we may then with sufficient accuracy calculate the tension, $T$, under the supposition that the stiffener has deflected as it would do under pure bending with the same maximum deflection and under a uniform load.

This supposition furnishes us in all cases with a simple equation of the first degree in $T$. The expression for $T$ depends only on the elasticity of the material and on the ratio between the deflection and the length, $\frac{\delta}{l}$, and is thus entirely independent of how the deflection has been produced, and of the moment of inertia of the stiffener.

The tension so found is likely to be an outside maximum value, for the supports of a stiffener are rarely absolutely immovable, nor are the attachments absolutely rigid, such as supposed in the formulas.

By applying this method to actual bulkhead tests it is found, that with

the deflections ordinarily considered permissible, the tension is generally so small that it may be neglected, or, if it is desired to take it into account, the tensional stress so found may be simply added to the stress due to pure bending. In fact, as long as $\delta$ does not exceed about $\frac{l}{200}$, the tension will be less than one ton per square inch. (See table of stresses and deflections on page 12 and the numerical example given at the end of the Appendix.) If in the design of new bulkheads we desire to examine the value of the tension, we may with sufficient accuracy calculate the deflection for pure bending and use the value of $\delta$ so found in the determination of $T$.

Only in extreme cases need we use the formulas for combined tension and bending, but in view of the tension being determined independently, as explained above, the treatment of the problem of a stiffener fixed at the ends, which was given in last year's paper, has been somewhat modified and extended in the Appendix of the present paper.

In the case of uniform load it has been found possible altogether to avoid the expansion of the exponential functions. In the case of uniform plus increasing load such expansion is unavoidable, as a convenient solution cannot otherwise be obtained, and it has been found necessary to extend the expansion somewhat further than given in last year's paper in order to obtain sufficient accuracy.

## II. Analysis of Bulkhead Tests.

### *a.* Description of Tests.

The tests here analyzed were carried out on bulkheads of rectangular form stiffened by a system of vertical, equidistant stiffeners of uniform section. This system is used in several navies, it has recently been adopted by Lloyds and Veritas and has been used for some time by several other Classification Societies; it is therefore of greater interest and importance than any other system of stiffening. The tests fall in two classes, those where the stiffeners are double, *i. e.*, placed on both sides of the bulkhead, as in Fig. 4, *a*, and those where the stiffeners are single, as in Fig. 4, *b*.

FIG. 4.

The total number of analyzed tests here recorded is fourteen, of which six were with double stiffeners, eight with single stiffeners; but several of these tests were made at two or more heads of water. The main results are given on Plates 28–31, and each test is given a number for reference.

In cases where deflections were measured at several different heads of water on the same bulkhead, the test generally commenced with a small or moderate head, increasing in stages up to the maximum. After the deflections at maximum head had been taken, the pressure was removed by letting the water run off completely, whereafter the permanent set was measured. The permanent set so found corresponds therefore only to the maximum head, and is not applicable to the deflections measured at the smaller heads, which existed prior to the maximum. For the purpose of analysis it would therefore be preferable to proceed in the reverse order, first subjecting the bulkhead to the maximum head and then to the smaller heads, since in that case the permanent set, measured after the test, would be applicable to all the readings.

Only in case of test No. 7 was this order of procedure followed.

### *b.* METHOD OF ANALYSIS.

The deflections used in this analysis, represented on the diagrams by heavy lines, are always the elastic deflections, *i. e.*, the observed deflections minus the permanent set. They are marked: "Obs. Elast. Defl.," and are drawn through the observed points irrespective of fairness of the curve, generally representing the mean deflections for two or more stiffeners. The curves of permanent set are given in dotted lines.

In cases where deflections have been measured at smaller heads previous to the maximum, the permanent set to be deduced has been estimated as a fraction of that found after the stiffeners had been exposed to the maximum head. In all cases where such estimate has been made it is clearly stated on the diagrams.

The curves of observed deflections refer in all cases to the middle stiffener or stiffeners in order as far as possible to eliminate the influence of the bulkhead plating in supporting the stiffeners by its tension.

The first question which occurs in the analysis is whether the tension, $T$, of the stiffeners shall be taken into account. As stated above it was found, in most of the cases here analyzed, that the tension might be neglected or that it might be found approximately and then simply added to the stress corresponding to pure bending. Only in one case, that of test No. 12, did the tensional stress exceed one ton per square inch, but, as evi-

denced by the great permanent set, $1\frac{1}{4}$ inches in 9 feet, this case is rather exceptional. (See table of stresses and deflections, page 94.)

The next question to be examined is whether brackets, when such are fitted, shall be considered effective, and to what degree, or in other words, which formula will in each case most nearly conform to the actual conditions, the formula for a stiffener fixed at the ends or that for a stiffener freely supported at the ends.

In order to settle this point, curves of deflection have been calculated according to both of these formulas, and these curves are shown in light lines on the diagrams. A comparison between the observed and the calculated curves will at once show which of the two assumptions is nearest the truth, but due regard must be paid to the rigidity of the structure to which the bracket is attached.

The length, $l$, of the stiffeners chosen for the calculations of this analysis was, in case of the formula for both ends fixed, the actual length of the main bar of the stiffener, denoted by $l$, and the same length was used where one end was unbracketed and the other efficiently bracketed, in which case the formula for one end free, the other end fixed, was employed. In the formula for both ends freely supported, when employed to stiffeners bracketed at both ends, the length, $l_2$, was measured between the apices of the brackets. This is clearly indicated on the diagrams. This choice of length is of course arbitrary, but has been found to lead to a fair correspondence with the observed results in case of double stiffeners. In comparing the curves it is well to bear in mind that the deflection varies as the fourth or fifth power of the length.

In calculating the moment of inertia of the double stiffeners, the bulkhead plating, which is here placed at the neutral axis, has been neglected, but in case of the single stiffeners it was found that a certain strip of the bulkhead plating ought to be considered as forming part of and as working with the stiffeners. If this strip was not included, the curve of deflection, calculated for both ends fixed, would, in case of the single stiffeners of the United States ships, fall considerably outside the curve for the observed elastic deflection even in the largest bulkheads. This does not seem possible, for since absolute rigidity in the brackets and in the supporting structure can never be secured, we should rather expect the calculated curve to fall inside the observed curve. It appears, therefore, that the moment of inertia of the stiffeners has been underestimated, but by including a strip of bulkhead plating of a certain width, the moment of inertia may be increased so as to make the calculated curve of deflection coincide with the observed curve. The width of this strip in the present analysis

has been assumed about 8 inches in case of the 12-inch I stiffeners with face plate, while, for stiffeners with only one flange and one line of rivets on the bulkhead, as in tests 12, 13 and 14, the width is assumed 5 inches. (See Plates 30 and 31.)

We might expect that single stiffeners would behave differently, according as the pressure was applied on the same side of the bulkhead as the stiffeners or on the opposite side. With the limited number of tests that would bring out this point, and which have been at the disposal of the author, it has not, however, been possible to arrive at any conclusion on this question, especially as some of the results are in this respect contradictory.

In accordance with the considerations concerning the effect of brackets, which have been given above, the stresses in the stiffeners have been calculated corresponding to the maximum bending moment existing in the free part of the stiffener between the brackets. This maximum was found, in all the cases here analyzed, near the middle of the stiffener, being here greater than at the apex of the brackets.

### *c.* RESULTS OF THE ANALYSIS WITH DISCUSSION.

*Comparison between double and single stiffeners.*—As will be seen by an inspection and comparison of the diagrams for double stiffeners given on Plates 28 and 29 and those for single stiffeners given on Plates 30 and 31 a very marked difference was found in the behavior of the two kinds of stiffeners. In practically all cases the observed curve of deflection of double stiffeners, tests Nos. 1 to 6, corresponded fairly with the curve calculated under the assumption that the stiffeners were freely supported at the apices of the brackets, and this in spite of the fact that the brackets, fitted both at the top and the bottom of the stiffeners, were very substantial. In most cases the brackets of the double stiffeners were indeed small, only of 18 inches effective height or $\frac{1}{14}$ to $\frac{1}{15}l$, and this might be thought to account for the great deflection, but even in cases where, as in test No. 6, the brackets were replaced by a rigid engine foundation, the deflection was still very considerable and approached that of a freely supported stiffener.

The single stiffeners, where bracketed efficiently, behaved on the other hand as if fixed at the ends, showing, relatively, a much smaller deflection than the double stiffeners. Considering first the tests Nos. 7 to 11, all of which took place in vessels of the United States Navy, the stiffeners are provided with large, very efficient 3-foot brackets, but are otherwise of much lighter construction than the double stiffeners. The weight per foot run of

these stiffeners is in fact only 45 pounds as against 77 pounds per foot run of the double stiffeners, and their moment of inertia is little more than two-thirds the moment of inertia of these latter. Whether bracketed at both ends or at the foot only, a close correspondence is generally found between the calculated and the observed curve. On the whole these tests, as well as others not here recorded, seem to warrant the statement, that stiffeners of the type and spacing here used and bracketed at both top and bottom may be expected to behave as fixed at the ends under the assumptions here made and within the theoretical stresses to which they have been exposed in these tests.

The cause of the greater efficiency of the single stiffeners must be sought in their more rational construction. These stiffeners are constructed of single I-bars of great depth with a face plate on the free flange, and are connected by two lines of rivets to the bulkhead plating, whereby this plating is enabled to work with the stiffener. (See Fig. 4, *b*.) Having no riveted connections, the I-bar itself presents no weakness, and the flanges are connected by a solid web.

By the double stiffeners the connection of the Z-bars along the neutral axis is effected by a single line of rather open-spaced rivets, passing through four thicknesses (two flanges, one liner and one bulkhead plate). (See Fig. 4, *a*.) This connection is ill adapted to resist the great lengthwise shearing forces which exist along the neutral axis near the apex of the brackets. A small sliding is liable to take place in the plane of the neutral axis, and the two stiffeners, which together make up a double stiffener, will then to some extent behave as if they were independent of each other. The points of inflexion will move nearer to the brackets, and it is not difficult to understand that the stiffener will now behave approximately as if free to turn about the apex of the brackets.

This weakness of the double stiffeners was observed already by Woodward in his tests of the center-line bulkhead of the Illinois. (See Plate 28, test No. 1.) It was then found, that although the brackets did not show any sign of yielding, the permanent set of the stiffeners as well as their elastic deflection were excessive, indicating a weakness in the stiffeners themselves independent of the bracketing.

It seems likely that all double stiffeners here analyzed suffer from the same weakness as the Illinois's stiffeners, a too small effective moment of inertia, even although a small height of bracket may be in some cases responsible in some measure for the great deflection. It is of course possible to avoid the weakness here referred to by connecting the bars on opposite sides more intimately with each other, for instance by means of two lines of closely spaced rivets, but in such case the flanges meeting on

the bulkhead must be broader or double, and we shall thus have a great accumulation of material at the neutral axis, which is not rational.

Thus we may say that double stiffeners are less efficient, heavier and more expensive than single stiffeners, and to this must be added that double stiffeners interfere with the caulking of the seams of the bulkhead plating.

Single stiffeners should therefore be used in all cases except where double stiffeners must be used for some special reason.

In test No. 12 the load was excessive as evidenced by the great permanent set and by the high theoretical stress, which exceeded the elastic limit. The curve for elastic deflection followed, however, also in this case closely the theoretical curve.

Test No. 13 was on a bulkhead constructed according to the Rules of Germanischen Lloyds. The head was also here very great, and the brackets were not of an effective type; hence the great deflection, which, as shown on the diagram, exceeds that of a freely supported stiffener if the length is reckoned from bracket to bracket. By reckoning the length slightly greater, 14.75 feet instead of 13.0 feet, the calculated curve of deflection may be made to correspond very closely with the observed curve. In calculating the stress this case has therefore been dealt with as that of a stiffener freely supported at the ends and of a length equal to 14.75 feet.

In test No. 14, which was on a bulkhead of the Russian Cruiser Bojarin, the bracketing was feeble and not connected to a rigid structure. Hence the length used in the calculation is here the total length of the main bar of the stiffener, but even so the observed deflection exceeds the calculated deflection somewhat. This shows the importance of strengthening and supporting the inner bottom where brackets are fitted to it.

Allowing for the reinforcement given by the brackets, the maximum stress was, as stated above, found to exist at or near the middle of the stiffeners. The stress was calculated first for pure bending, supposing the stiffeners to carry the full load on one span. In accordance with the above the formula for a freely supported stiffener was used in case of most of the double stiffeners, while the formulas for stiffeners fixed at one or both ends, in accordance with the system of bracketing, were used in case of most of the single stiffeners. Thereafter the stress due to pure tension was calculated corresponding to the observed deflection, as explained in the Appendix, and added to the stress due to bending.

It was not found necessary or useful, in determining the stress, to apply the complex formulas for combined tension and bending to the tests here analyzed.

The following table gives the results of the calculations:—

## Table of Stresses and Deflections.

| Test No. | Type of stiffener. | Assumed condition. | Length $l$ feet. | Head above top of stiffener $h$ feet. | Span $s$ feet. | Section modulus $\frac{I}{y}=S$. | Stress under maximum head. Pure bending. Tons per square inch. | Stress under maximum head. Pure tension. Tons per square inch. | Total stress. Tons per square inch. | Calculated elastic deflection. Pure bending. Inches. | Observed elastic deflection. Inches. | Observed permanent set. Inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Double. Two 6″ Z-bars. Reversed bars at top and bottom. | Both ends fixed..... | 22.16 | 2.76 | 4.0 | 20.1 | 19.4 | .9 | 20.3 | 1.01 | 1.38 | 1.24 |
| 2 | Double. Two 6″ Z-bars with reversed angles and face plates the entire length of the stiffeners. | Both ends free..... | 16.92 | 4.01 | 4.0 | 47.5 | 13.0 | .4 | 13.4 | .65 | .72 | .16 |
| 3 | | Both ends free..... | 19.17 | 9.76 | 4.0 | 99.2 | 12.4 | .5 | 12.9 | .79 | .94 | .52 |
| 4 | | Both ends free..... | 18.79 | 10.67 | 4.0 | 98.7 | 12.4 | .4 | 12.8 | .75 | .78 | .28 |
| 5 | | Both ends free..... | 18.75 | 11.25 | 4.0 | 98.7 | 12.7 | .5 | 13.2 | .78 | .83 | .52 |
| 6 | | Both ends free..... | 19.08 | 10.42 | 4.0 | 79.6 | 15.7 | .2 | 15.9 | 1.01 | .58 | .44 |
| 7 | Single. One 12″ I-bar with face plate. | Both ends fixed..... | 22.90 | 9.50 | 4.0 | 61.4 | 10.3 | .2 | 10.5 | .51 | .55 | .22 |
| 8 | | Upper end free, lower end fixed. | 26.17 | 0.00 | 4.0 | 61.4 | 11.7 | .3 | 12.0 | .97 | 1.00 | .25 |
| 9 | | Both ends fixed..... | 25.92 | 5.42 | 4.0 | 61.4 | 11.7 | .4 | 12.1 | .75 | .69 | .19 |
| 10 | | Both ends fixed..... | 25.00 | 6.33 | 4.0 | 61.4 | 11.2 | .2 | 11.4 | .66 | .63 | .09 |
| 11 | | Upper end free, lower end fixed. | 25.50 | 5.83 | 4.0 | 61.4 | 16.8 | .4 | 17.2 | 1.56 | 1.26 | .87 |
| 12 | Single. 6″ channel-bar.. | Upper end fixed, lower end free. | 9.0 | 24.4 | 4.0 | 9.3 | 25.2 | 1.4 | 26.6 | .61 | .60 | 1.22 |
| 13 | Single. 13.4″ channel-bar. | Both ends free..... | 14.75 | 24.6 | 2.50 | 49.7 | 15.1 | .3 | 15.4 | .47 | .47 | not known |
| 14 | Single. 8.66″channel-bar with reversed angle. | Both ends free..... | 14.58 | 3.0 | 2.75 | 27.6 | 9.4 | .4 | 9.8 | .50 | .60 | .19 |

It will be seen from this table, that for the double stiffeners of the type here tested it would be safe to allow a stress of 12 tons per square inch if same assumptions are made as in the present calculations.

For single stiffeners a permissible stress in pure bending of 10 tons per square inch has been chosen, and this figure has been used as basis for the accompanying tables. As seen from the table of stresses, tests Nos. 11 and 12, where the stiffeners were fixed at one end only, much higher stresses may be reached without any breakdown taking place, but it will be noticed that the permanent set is considerable in these cases, and it appears preferable to bracket both ends and to allow only the more moderate stress. It is argued that since stiffeners so constructed have proved themselves to be not only safe but to have a very small permanent set, we shall arrive at a satisfactory construction of stiffeners in the design of new bulkheads, even if of very different type, if we make similar assumptions, and if we keep within the stresses found in the present analysis.

## III. General Rules for the Construction of Water-tight Bulkheads.

While the following rules are essentially a résumé of the foregoing, they are based also largely on tests, experience and practise, which space does not permit to reproduce or discuss in this paper. Among the material drawn upon may be mentioned a great number of tests, too incomplete or of too complex a nature to permit an analysis, and further the current practise of various foreign navies and the rules of the Classification Societies.

The rules here given apply only to ordinary water-tight bulkheads, not to deep tank or to oil-tight bulkheads.

1. A pure system of uniformly spaced vertical stiffeners and horizontal strakes of plating should be used, except where the horizontal extension of the bulkhead is smaller than its height, and where at the same time the brackets of horizontal stiffeners can obtain a rigid attachment, in which case a pure system of horizontal stiffeners should be used. This last condition is fulfilled only in few cases, such as in collision bulkheads. In the majority of bulkheads vertical stiffeners are the most efficient as far as strength under water pressures is concerned.

2. The thickness or weight per square foot of the plating may be determined on the basis of its depth below or its height above the water-line, which corresponds to the deepest draught to which the ship may reasonably be assumed to be immersed in damaged condition. As a general rule it is proposed to make the weight of the strake immediately below this water-line not less than 7 pounds per square foot, and to add one pound for each

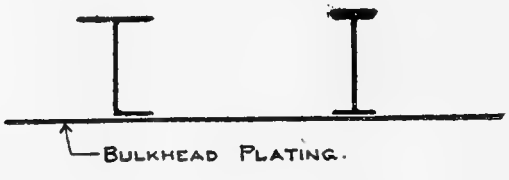
additional 4-feet depth or $\frac{1}{32}$ inch for each additional 5-feet depth. For plating above this water-line the weight should be decreased at the same rate. The thicknesses determined by this rule should be considered as minimum thicknesses, and must in many cases be increased to provide for corrosion, for general or local structural strength, or for the forces to which the plating may be exposed by the stowage of cargo.

Below the normal load water-line both butts and seams should be double riveted.

3. The stiffeners should be single, *i. e.*, each individual stiffener should be placed on one side of the bulkhead only. On all stiffeners of any importance a face bar or a reversed bar should be fitted on the free flange so as to balance as nearly as possible the strip of the bulkhead plating, which may be assumed to work with the stiffener.

A more efficient solution could be obtained with bars of sections as indicated on Fig. 5, where one flange is heavier than the other.

FIG. 5.




This would obviate the necessity for face plates or reversed bars, but it is a question whether such bars could be rolled without too great extra cost.

With the thicknesses of plating recommended above, the spacing of the stiffeners should not exceed 4 feet. The stiffeners should all be placed on the same side of the bulkhead.

4. The stiffeners should be provided with efficient brackets both at top and bottom, constructed as indicated on Fig. 1, *c* by splitting the main bar of the stiffeners, whether I, ⌋, ⌊ bars or bulbs. The face plate, if any, should be continued the whole length of the bracket and should have a good end connection. The height and width of the lower bracket should be about three times the depth of the stiffener, but in no case should the height fall below one-tenth of the length of the stiffener. The sides of the upper bracket may be about ten per cent. shorter than those of the lower bracket.

The brackets should be attached to a rigid part of the ship's structure,

such as a floor plate, a longitudinal or a deck beam, or else reinforcements must be introduced.

5. The bounding angles in all important bulkheads should be double up to a height of about 5 feet below the load water-line.

## EXPLANATION OF BULKHEAD TABLES I AND II.

The use of these tables is recommended only in case the bulkheads are constructed in accordance with the above rules.

As basic arguments of the tables are chosen the length of the stiffener, $l$, and the head of water above or below the top of the stiffener, $h$, both measured in feet.

With the construction of brackets here proposed $l$ may be taken equal to the entire height of the bulkhead except where, as may occur in a longitudinal bulkhead, the stiffeners are bracketed to deck beams, in which case $l$ should be measured from the underside of the beams. In any case $l+h$ is the total head at the foot of the stiffener, and it is assumed that the stiffener is unsupported except at the ends.

The value of $h$ should be chosen so as to correspond to the deepest draught to which the ship may presumably be immersed when in damaged condition. This draught should be chosen with due regard to type and size of ship, and to the longitudinal and transverse location of the bulkhead, for if placed near the ends or near the sides it may become subject to greater heads than when placed near half length or at the center-line of the ship. Regard should also be had to the fact that the water in a flooded compartment may be put in violent motion when the ship is pitching and rolling.

Assuming the bulkheads to be constructed in accordance with the above rules, the section modulus required for stiffeners with different given values of $l$, $h$ and $s$ (span) has been calculated as follows:—

Let the total load on one stiffener be denoted by $P$, then—

$$P = \frac{s}{35}\left(h+\frac{l}{2}\right)l \text{ tons},$$

where $h$, $l$ and $s$ are in feet. The bending moment is taken equal to $\frac{Pl}{24}$, which is very approximately the maximum near the middle of a stiffener fixed at both ends and under all conditions of loading. With brackets of the height required by above rules this maximum will be the absolute maximum everywhere in the free portion of the stiffener between the brackets. (See Fig. 3.) We obtain thus:—

$$M=\frac{Pl}{24}=\frac{(h+\frac{l}{2})l^2s}{70} \text{ inch-tons,}$$

and the required section modulus—

$$S=\frac{I}{y}=\frac{M}{f}=\frac{(h+\frac{l}{2})l^2s}{700},$$

taking the permissible stress, $f$, equal to ten tons per square inch as explained above.

If the top of the bulkhead is $h$ feet above the water-line of deepest immersion, the maximum bending moment may still be reckoned equal to $\frac{Pl}{24}$, but now—

$$P=\frac{s}{70}(l-h)^2 \text{ tons,}$$

and hence—

$$S=\frac{(l-h)^2ls}{1400}.$$

The section moduli so determined are given in Table I for a series of values of $l$, $h$ and $s$ ranging between the extremes of present practise.

In Table II are given the section moduli of several series of different types of stiffeners, both with and without face plates or reversed bars. Since the value of $f$, which enters in the calculation of $S$ in Table I, has been chosen under the assumption that the bulkhead plating contributes to the strength of the stiffener, the same assumption has been made in the calculation of $S$ as given in Table II. In general a strip of bulkhead plating of about same sectional area as that of the flange which is attached to the bulkhead has been assumed to work with the stiffener. Where a face plate is added to the free flange of the stiffener, it has likewise been given about the same sectional area as the flange so as to balance approximately the hypothetical strip of bulkhead plating. Thus the neutral axis of a stiffener with face plate will come to lie theoretically at the middle of the web of the bar.

The bars given in Table II are partly those manufactured by the Carnegie Steel Company, partly the Standard British Sections.

The use of the tables is simple. Corresponding to the given values of $l$, $h$ and $s$, the required section modulus is found from Table I, and the most appropriate stiffener can then readily be selected from Table II.

In Table I is also given the thickness of the bulkhead plating, the figures referring to the upper and lower strakes. Intermediate strakes should in general be increased one pound or $\frac{1}{32}$ of an inch for each strake going downward, depending of course on the width of the strakes.

Plate 32 shows the application of the tables to some typical bulkheads.

In concluding this paper I wish to acknowledge my indebtedness to the successive Chief Constructors of the United States Navy: Rear-Admiral F. T. Bowles, Rear-Admiral W. L. Capps, and Rear-Admiral R. M. Watt, for having so generously placed at my disposal, during the last eight years, the results of bulkhead tests carried out in the United States Navy, and for having permitted their publication.

To Mr. Henry H. W. Keith, S. B., and to Mr. K. T. Blood, S. B., of the Massachusetts Institute of Technology, my thanks are due for their assistance in the comprehensive numerical and graphical work involved in the paper.

# APPENDIX.

## NOTATION.

$w$ = The load on the stiffener. For salt water and for a span of $s$ feet:

$w = 64s$ lbs. $= \frac{s}{35}$ tons per foot run and per foot head.

$h$ = Head of water at top of stiffener.

$C$ = Length of stiffener.

$p$ = Pressure per unit length of the stiffener at any point, distant $x$ from the top: $p = w\ (h + x)$.

$P_A$ = Horizontal component of the supporting forces at the top of the stiffener, $A$.

$P_B$ = Horizontal component of the supporting forces at the bottom of the stiffener, $B$.

$M_X$ = Bending moment at any point at a distance $x$ from the origin.

$T$ = Tension in stiffener.

$A$ = Sectional area of stiffener.

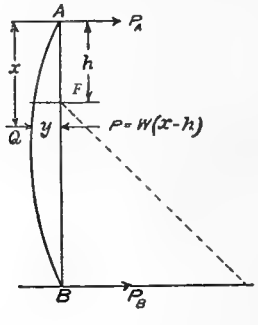
$I$ = Moment of inertia of stiffener.

$E$ = Modulus of elasticity.

## FORMULAS FOR THE CASE WHERE THE LEVEL OF THE WATER IS BELOW THE TOP OF THE STIFFENER.

### 1. STIFFENER FREELY SUPPORTED AT THE ENDS.

FIG. 6.




Let the water level be at a distance $AF = h$ below the top of the stiffener, and let us deal first with the lower portion of the stiffener $FB$.

Take origin at $A$ and consider a point $Q$, distant $x$ from $A$ and $x - h$ below $F$. Taking moments about $Q$—

$$M_X = EI\frac{d^2y}{dx^2} = -P_A x + \frac{w(x-h)^3}{6} \tag{1}$$

$$\therefore EI\frac{dy}{dx} = -\frac{P_A x^2}{2} + \frac{w(x-h)^4}{24} + C_1 \tag{2}$$

and

$$EIy = -\frac{P_A x^3}{6} + \frac{w(x-h)^5}{120} + C_1 x + C_2 \tag{3}$$

For the upper portion of the stiffener $AF$—

$$M_X = EI\frac{d^2y}{dx^2} = -P_A x \tag{4}$$

$$\therefore EI\frac{dy}{dx} = -\tfrac{1}{2}P_A x^2 + C_1' \tag{5}$$

but since $\frac{dy}{dx}$ must be the same at the point $F$ both in (2) and (5), we find $C_1' = C_1$.

Integrating (5):—

$$EIy = -\tfrac{1}{6}P_A x^3 + C_1 x + Cl_2' \tag{6}$$

and since $y$ must be the same in (3) and (6) when $x=h$, we find $C_2' = C_2$, and from (6) since $y=o$ when $x=o$: $C_2 = o$.

When $x=l$, $M_X = o$, hence from (1)—

$$P_A = \frac{w(l-h)^3}{6l} \tag{7}$$

When $x=l$, $y=o$, $\therefore$ from (3)—

$$C_1 = \frac{P_A}{2}\left[\frac{l^2}{3} - \frac{(l-h)^2}{10}\right] \tag{8}$$

Thus we obtain:—Above $F$—

$$M_X = -P_A x \tag{9}$$

$$EI\frac{dy}{dx} = \frac{P_A}{2}\left[\frac{l^2}{3} - \frac{(l-h)^2}{10} - x^2\right] \tag{10}$$

$$EIy = -\frac{P_A}{6}x^3 + \frac{P_A}{2}\left[\frac{l^2}{3} - \frac{(l-h)^2}{10}\right]x \tag{11}$$

Below $F$—

$$M_X = -P_A x + \frac{w(x-h)^3}{6} \tag{12}$$

$$EI\frac{dy}{dx} = -\frac{P_A}{2}x^2 + \frac{w(x-h)^4}{24} + \frac{P_A}{2}\left[\frac{l^2}{3} - \frac{(l-h)^2}{10}\right] \tag{13}$$

$$EIy = -\frac{P_A}{6}x^3 + \frac{w(x-h)^5}{120} + \frac{P_A}{2}\left[\frac{l^2}{3} - \frac{(l-h)^2}{10}\right]x \tag{14}$$

$$P_B = \tfrac{1}{2}w(l-h)^2 - P_A \tag{15}$$

### 2. STIFFENER FIXED AT BOTH ENDS.

The solution follows the same lines as in case 1, and therefore only results shall here be given:—

Above $F$—

$$M_X = M_A - P_A x \tag{16}$$

$$M_A = \frac{w(l-h)^4}{12l} - \frac{w(l-h)^5}{20l^2} \tag{17}$$

$$P_A = \frac{w(l-h)^4}{4l^2} - \frac{w(l-h)^5}{10l^3} \tag{18}$$

$$EI\frac{dy}{dx} = M_A x - \tfrac{1}{2}P_A x^2 \tag{19}$$

$$EIy = \tfrac{1}{2}M_A x^2 - \tfrac{1}{6}P_A x^3 \tag{20}$$

Below $F$—

$$M_X = M_A - P_A x + \frac{w(x-h)^3}{6} \tag{21}$$

$$EI\frac{dy}{dx} = M_A x - \frac{P_A x^2}{2} + \frac{w(x-h)^4}{24} \tag{22}$$

$$EIy=\tfrac{1}{2}M_A x^2-\frac{P_A x^3}{6}+\frac{w(x-h)^5}{120} \tag{23}$$

$$M_B=\frac{w(l-h)^3}{60}\left[10-\frac{10(l-h)}{l}+\frac{3(l-h)^2}{l^2}\right] \tag{24}$$

$$P_B=\tfrac{1}{2}w(l-h)^2-P_A.$$

## Formulas for Tension and Bending Combined.

[Supplement to Appendix IIB, page 427 of the Transactions, 1909.]

### (*a*) determination of the tension, *T*.

Let us suppose that we know the maximum deflection of a stiffener either from a test of the bulkhead or from calculation under the assumption of simple bending. If, now, we knew the formula for the true curve of deflection, we could determine the tension corresponding to the elongation of the stiffener, assuming of course that the supports are absolutely fixed.

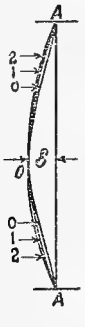
Since we do not know the actual curve of deflection, it is proposed to use in its stead the curve for pure bending with same maximum deflection.

In order to show that it is permissible to use this approximation, we shall first determine the relation between $T$ and the maximum deflection, $\delta$, when a stiffener is under a uniform load, $p$, per unit length.

*First Case—Elastic Stiffener. Ends fixed (curve o, fig. 7).*

FIG. 7.

CURVES OF DEFLECTIONS.




Taking origin at $O$, the middle of the stiffener in its deflected position, the equation to the curve of deflection is—

$$y=\frac{p}{24EI}\left(\frac{l^2x^2}{2}-x^4\right) \tag{1}$$

$$\therefore \frac{dy}{dx}=\frac{p}{24EI}\left(l^2x-4x^3\right).$$

The equation for elongation is:—

$$\frac{lT_0}{AE}=\int_0^{\frac{l}{2}}\left(\frac{dy}{dx}\right)^2dx=\frac{p^2l^7}{105\times 576E^2I^2},$$

from which—

$$T_0=\frac{Ap^2l^6}{105\times 576EI^2} \tag{2}$$

From (1)—

$$\delta=\frac{pl^4}{384EI} \tag{3}$$

From (2) and (3)—

$$T_0=\frac{256}{105}\frac{AE\delta^2}{l^2}=2.44AE\frac{\delta^2}{l^2} \tag{4}$$

*Second Case—Elastic Stiffener. Ends hinged* (*curve* 1, *fig.* 7).

The equation to the curve of deflection is here—

$$y=\frac{p}{8EI}\left(\frac{l^2x^2}{2}-\frac{x^4}{3}\right) \tag{5}$$

and proceeding as in first case, the elongation furnishes a value for the tension:—

$$T_1=\frac{17Ap^2l^6}{128\times 315EI^2} \tag{6}$$

$$\delta=\frac{5pl^4}{384EI} \tag{7}$$

From (6) and (7)—

$$T_1=\frac{2176}{875}\frac{AE\delta^2}{l^2}=2.49AE\frac{\delta^2}{l^2} \tag{8}$$

*Third Case—Elastic String (curve 2, fig. 7).*

This case is given because it furnishes an outer value of the elongation and hence of the tension for a given maximum deflection. As explained in last year's paper (Appendix II, page 422), we have here:—

$$y=\frac{p}{2T}x^2 \tag{9}$$

which gives—

$$T_2^{\ 3}=\frac{1}{24}p^2l^2AE \tag{10}$$

$$\delta=\frac{pl^2}{8T} \tag{11}$$

whence—

$$T_2=\frac{8AE\delta^2}{3l^2}=2.67AE\frac{\delta^2}{l^2} \tag{12}$$

Comparing now the three values of $T$ as found by (4), (8) and (12) we see that $T_2$ is about seven per cent. greater than $T_1$ and $T_1$ about two per cent. greater than $T_0$.

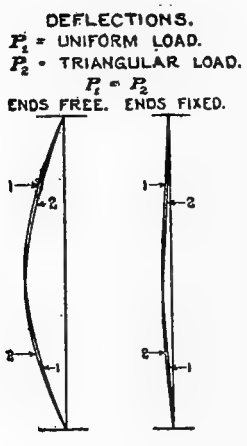
The actual curve of deflection when tension is included will, for a given value of $\delta$, both in the first and second cases, fall somewhat outside the respective curves for pure bending 0 and 1, and in case of stiffeners with very small moment of inertia the actual curve of deflection will approach curve 2, which gives the absolute maximum value of the tension. (See Fig. 7.)

With the stiffness usually possessed by bulkhead stiffeners the curve of deflection for a given value of $\delta$ will probably always fall very near the curve for pure bending, and we may therefore assert that the tension, as determined by (4) and (8) on the basis of a given deflection, is not likely to differ more than a few per cent. from the true value in all ordinary cases.

As shown on Fig. 8 the curve of deflection for a certain increasing load is very nearly of same length as that for the same uniform load, being inside the latter curve at the upper part and outside at the lower part. For combined uniform and increasing load the curve of deflection is intermediate between the two first named curves. We may thus without

sensible error use the above formulas for $T_0$ and $T_1$ not only for uniform load but also for increasing load and for combined uniform plus increasing load.

FIG. 8.




(*b*) FORMULAS FOR DEFLECTION, BENDING MOMENTS AND SUPPORTING FORCES.

Having thus determined $T$ independently, we may without undue complications use more perfect or complete expressions for $y$, $M$ and $P$ than were given in last year's paper:—

1. STIFFENER *AA* FIXED VERTICALLY AT BOTH ENDS AND LOADED BY A UNIFORM LOAD $wh=p$.

Referring to last year's paper, Appendix II, page 427, we may now avoid the expansion of the exponential functions, since $n=\sqrt{\frac{T}{EI}}$ can be determined at once.

Let

$$e^{\frac{nl}{2}}+e^{\frac{-nl}{2}}=\alpha \quad \text{and} \quad e^{\frac{nl}{2}}-e^{\frac{-nl}{2}}=\beta$$

we then obtain:—

$$y=\frac{p}{2T}\left[x^2-\frac{l}{n\beta}\left(e^{nx}+e^{-nx}-2\right)\right] \tag{13}$$

$$\delta=\frac{pl}{2T}\left[\frac{l}{4}-\frac{\alpha-2}{n\beta}\right] \tag{14}$$

$$M_0=\frac{p}{n^2}-\frac{pl}{n\beta} \tag{15}$$

$$M_A=\frac{p}{n}\left[\frac{1}{n}-\frac{l\alpha}{2\beta}\right] \tag{16}$$

$$P_A=\tfrac{1}{2}pl. \tag{17}$$

The value of $T$ here used is denoted above as $T_0$ and determined by equation (4). The value of $M_x$ is as given in last year's paper, page 427.

2. STIFFENER *AB* FIXED VERTICALLY AT BOTH ENDS AND LOADED BY A COMBINED UNIFORM AND INCREASING LOAD.

$$p=w\ (h+x).$$

Referring to last year's paper, Appendix II, page 431, we cannot here retain the exponential terms without obtaining very cumbrous expressions, but in order to obtain greater accuracy than was the case in last year's paper, the expansion of the exponential terms has been carried to the sixth power. In fact, it has been found that expansion to the fourth power is not, as stated in last year's paper, always sufficient. We then obtain the following expressions:—

$$y=\frac{M_A}{2EI}x^2-\frac{P_A}{6EI}x^3+\frac{1}{24EI}\left(\frac{M_AT}{EI}+wh\right)x^4+\frac{1}{120EI}\left(w-\frac{P_AT}{EI}\right)x^5 + \left(\frac{M_AT}{EI}+wh\right)\frac{x^6T}{720E^2I^2} \tag{18}$$

Let $$\frac{Tl^2}{12EI}=k,$$

$$M_A=\frac{wl^2}{12}\left(\frac{5h+2l+3hk}{5+4k}\right) \tag{19}$$

$$M_B=\frac{wl^2}{12}\left(\frac{5h+3l+3hk+5kl}{5+4k}\right) \tag{20}$$

$$P_A=\frac{wl}{4}\,\frac{10h+3l+kl+8hk}{5+4k} \tag{21}$$

$$P_B = whl + \tfrac{1}{2}\, wl^2 - P_A \qquad (22)$$

$$M_X = M_A + Ty - P_A x + \tfrac{1}{2} whx^2 + \tfrac{1}{6} wx^3. \qquad (23)$$

The value of $T$ used in this case is again that denoted by $T_0$, determined by equation (4).

*Numerical Example—To Determine Tension, Deflection, Stresses, etc., in Stiffener No. 62 of C. L. B. H. Illinois, Test No. 1, Plate I.*

$l = 22.16$ feet, $h = 2.76$ feet, $w = \frac{4}{35}$ ton per foot run per foot head.

$A = 8.44$ square inches, $I = 128$ (in.)$^2$ square inches, $E = 13{,}170$ tons per square inch.

The elastic deflection was measured:—$\delta = 1.38$ inch.

Considering the stiffener fixed at both ends we find from (4):—

$$\frac{T}{A} = 2.44 E \frac{\delta^2}{l^2} = .86 \text{ tons per square inch.}$$

Hence $T = 7.23$ tons. Further $k = .0253$.

If we reckon the bending moment at the middle of the stiffener $= \frac{1}{24}(P_1 + P_2)l$ we find $M = 389$ inch-tons, which would give the maximum stress due to simple bending:—$f = 19.4$ tons per square inch, to which the tension .86 tons per square inch should be added.

Using the complex formulas (18), (19), (20), (21), (22) given above for combined tension and bending we find the results given in the first column of the following table, while the second column gives the results for simple bending.

| | Tension and bending combined. | Simple bending. |
|---|---|---|
| $y$ maximum..... | .99 inch. | 1.02 inch. |
| $M_A$..... | 641 inch-tons. | 652 inch-tons. |
| $M_B$..... | 916 inch-tons. | 901 inch-tons. |
| $P_A$..... | 11.8 tons. | 11.9 tons. |
| $P_B$..... | 23.3 tons. | 23.2 tons. |

It is seen that the difference between the results in the two columns is insignificant in this case, although the deflection is greater than usual and the stiffener has been strained beyond the elastic limit. In general, therefore, we may use the formulas for simple bending and to the stress so found we may, if desired, add the tensional stress determined as explained above by means of the observed or calculated deflection.

## TABLE I.—THICKNESS OF BULKHEAD PLATING AND SECTION MODULUS OF STIFFENERS.

$l$ = Length of stiffener. $h$ = head of water above top of stiffener. $s$ = span of stiffeners. $S = \frac{I}{y}$ = Section modulus where $I$ is the moment of inertia about the neutral axis, $y$ is the distance of the most strained fiber from the neutral axis.

| $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | | $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 8 | −4 | 6 | 7 | .18 | .23 | .27 | .37 | 8 | 30 | 15 | 16 | 6.2 | 7.8 | 9.3 | 12.4 |
| 8 | −2 | 7 | 8 | .41 | .51 | .62 | .82 | 8 | 32 | 15 | 16 | 6.6 | 8.2 | 9.9 | 13.2 |
| 8 | 0 | 7 | 8 | .73 | .91 | 1.1 | 1.5 | 8 | 34 | 16 | 17 | 7.0 | 8.7 | 10.4 | 13.9 |
| 8 | 2 | 8 | 9 | 1.1 | 1.4 | 1.6 | 2.2 | 8 | 36 | 16 | 17 | 7.3 | 9.1 | 11.0 | 14.6 |
| 8 | 4 | 8 | 9 | 1.5 | 1.8 | 2.2 | 2.9 | 8 | 38 | 17 | 18 | 7.7 | 9.6 | 11.5 | 15.4 |
| 8 | 6 | 9 | 10 | 1.8 | 2.3 | 2.7 | 3.7 | 9 | −4 | 6 | 7 | .32 | .40 | .48 | .64 |
| 8 | 8 | 9 | 10 | 2.2 | 2.7 | 3.3 | 4.4 | 9 | −2 | 7 | 8 | .63 | .79 | .95 | 1.3 |
| 8 | 10 | 10 | 11 | 2.6 | 3.2 | 3.8 | 5.1 | 9 | 0 | 7 | 8 | 1.0 | 1.3 | 1.6 | 2.1 |
| 8 | 12 | 10 | 11 | 2.9 | 3.7 | 4.4 | 5.8 | 9 | 2 | 8 | 9 | 1.5 | 1.9 | 2.3 | 3.0 |
| 8 | 14 | 11 | 12 | 3.3 | 4.1 | 4.9 | 6.6 | 9 | 4 | 8 | 9 | 2.0 | 2.5 | 3.0 | 3.9 |
| 8 | 16 | 11 | 12 | 3.7 | 4.6 | 5.5 | 7.3 | 9 | 6 | 9 | 10 | 2.4 | 3.0 | 3.7 | 4.9 |
| 8 | 18 | 12 | 13 | 4.0 | 5.0 | 6.0 | 8.0 | 9 | 8 | 9 | 10 | 2.9 | 3.6 | 4.3 | 5.8 |
| 8 | 20 | 12 | 13 | 4.4 | 5.5 | 6.6 | 8.8 | 9 | 10 | 10 | 11 | 3.4 | 4.2 | 5.0 | 6.7 |
| 8 | 22 | 13 | 14 | 4.8 | 5.9 | 7.1 | 9.5 | 9 | 12 | 10 | 11 | 3.8 | 4.8 | 5.7 | 7.6 |
| 8 | 24 | 13 | 14 | 5.1 | 6.4 | 7.7 | 10.2 | 9 | 14 | 11 | 12 | 4.3 | 5.4 | 6.4 | 8.6 |
| 8 | 26 | 14 | 15 | 5.5 | 6.8 | 8.2 | 11.0 | 9 | 16 | 11 | 12 | 4.7 | 5.9 | 7.1 | 9.5 |
| 8 | 28 | 14 | 15 | 5.9 | 7.3 | 8.8 | 11.7 | 9 | 18 | 12 | 13 | 5.2 | 6.5 | 7.8 | 10.4 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | | $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 9 | 20 | 12 | 13 | 5.7 | 7.1 | 8.5 | 11.3 | 10 | 16 | 12 | 13 | 6.0 | 7.5 | 9.0 | 12.0 |
| 9 | 22 | 13 | 14 | 6.1 | 7.7 | 9.2 | 12.3 | 10 | 18 | 12 | 13 | 6.6 | 8.2 | 9.9 | 13.1 |
| 9 | 24 | 13 | 14 | 6.6 | 8.2 | 9.9 | 13.2 | 10 | 20 | 13 | 14 | 7.1 | 8.9 | 10.7 | 14.3 |
| 9 | 26 | 14 | 15 | 7.1 | 8.8 | 10.6 | 14.1 | 10 | 22 | 13 | 14 | 7.7 | 9.6 | 11.6 | 15.4 |
| 9 | 28 | 14 | 15 | 7.5 | 9.4 | 11.3 | 15.0 | 10 | 24 | 14 | 15 | 8.3 | 10.4 | 12.4 | 16.6 |
| 9 | 30 | 15 | 16 | 8.0 | 10.0 | 12.0 | 16.0 | 10 | 26 | 14 | 15 | 8.9 | 11.1 | 13.3 | 17.7 |
| 9 | 32 | 15 | 16 | 8.4 | 10.6 | 12.7 | 16.9 | 10 | 28 | 15 | 16 | 9.4 | 11.8 | 14.1 | 18.9 |
| 9 | 34 | 16 | 17 | 8.9 | 11.1 | 13.4 | 17.8 | 10 | 30 | 15 | 16 | 10.0 | 12.5 | 15.0 | 20.0 |
| 9 | 36 | 16 | 17 | 9.4 | 11.7 | 14.1 | 18.7 | 10 | 32 | 16 | 17 | 10.6 | 13.2 | 15.9 | 21.1 |
| 10 | −4 | 7 | 8 | .51 | .64 | .77 | 1.0 | 10 | 34 | 16 | 17 | 11.1 | 13.9 | 16.7 | 22.3 |
| 10 | −2 | 7 | 8 | .91 | 1.1 | 1.4 | 1.8 | 10 | 36 | 17 | 18 | 11.7 | 14.6 | 17.6 | 23.4 |
| 10 | 0 | 8 | 9 | 1.4 | 1.8 | 2.1 | 2.9 | 11 | −4 | 6 | 8 | .77 | .96 | 1.2 | 1.5 |
| 10 | 2 | 8 | 9 | 2.0 | 2.5 | 3.0 | 4.0 | 11 | −2 | 7 | 8 | 1.3 | 1.6 | 1.9 | 2.5 |
| 10 | 4 | 9 | 10 | 2.6 | 3.2 | 3.9 | 5.1 | 11 | 0 | 7 | 9 | 1.9 | 2.4 | 2.9 | 3.8 |
| 10 | 6 | 9 | 10 | 3.1 | 3.9 | 4.7 | 6.3 | 11 | 2 | 8 | 9 | 2.6 | 3.2 | 3.9 | 5.2 |
| 10 | 8 | 10 | 11 | 3.7 | 4.6 | 5.6 | 7.4 | 11 | 4 | 8 | 10 | 3.3 | 4.1 | 4.9 | 6.6 |
| 10 | 10 | 10 | 11 | 4.3 | 5.4 | 6.4 | 8.6 | 11 | 6 | 9 | 10 | 4.0 | 5.0 | 6.0 | 8.0 |
| 10 | 12 | 11 | 12 | 4.9 | 6.1 | 7.3 | 9.7 | 11 | 8 | 9 | 11 | 4.7 | 5.8 | 7.0 | 9.3 |
| 10 | 14 | 11 | 12 | 5.4 | 6.8 | 8.1 | 10.9 | 11 | 10 | 10 | 11 | 5.4 | 6.7 | 8.0 | 10.7 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | | $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 11 | 12 | 10 | 12 | 6.0 | 7.6 | 9.1 | 12.1 | 12 | 10 | 10 | 12 | 6.6 | 8.2 | 9.9 | 13.2 |
| 11 | 14 | 11 | 12 | 6.7 | 8.4 | 10.1 | 13.5 | 12 | 12 | 10 | 12 | 7.4 | 9.3 | 11.1 | 14.8 |
| 11 | 16 | 11 | 13 | 7.4 | 9.3 | 11.1 | 14.9 | 12 | 14 | 11 | 13 | 8.2 | 10.3 | 12.3 | 16.5 |
| 11 | 18 | 12 | 13 | 8.1 | 10.2 | 12.2 | 16.3 | 12 | 16 | 11 | 13 | 9.1 | 11.3 | 13.6 | 18.1 |
| 11 | 20 | 12 | 14 | 8.8 | 11.0 | 13.2 | 17.6 | 12 | 18 | 12 | 14 | 9.9 | 12.3 | 14.8 | 19.8 |
| 11 | 22 | 13 | 14 | 9.5 | 11.9 | 14.3 | 19.0 | 12 | 20 | 12 | 14 | 10.7 | 13.4 | 16.0 | 21.4 |
| 11 | 24 | 13 | 15 | 10.2 | 12.8 | 15.3 | 20.4 | 12 | 22 | 13 | 15 | 11.5 | 14.4 | 17.3 | 23.0 |
| 11 | 26 | 14 | 15 | 10.9 | 13.6 | 16.3 | 21.8 | 12 | 24 | 13 | 15 | 12.3 | 15.4 | 18.5 | 24.7 |
| 11 | 28 | 14 | 16 | 11.6 | 14.5 | 17.4 | 23.2 | 12 | 26 | 14 | 16 | 13.2 | 16.5 | 19.7 | 26.3 |
| 11 | 30 | 15 | 16 | 12.3 | 15.3 | 18.4 | 24.5 | 12 | 28 | 14 | 16 | 14.0 | 17.5 | 21.0 | 28.0 |
| 11 | 32 | 15 | 17 | 13.0 | 16.2 | 19.4 | 25.9 | 12 | 30 | 15 | 17 | 14.8 | 18.5 | 22.2 | 29.6 |
| 11 | 34 | 16 | 17 | 13.7 | 17.1 | 20.5 | 27.3 | 12 | 32 | 15 | 17 | 15.6 | 19.5 | 23.5 | 31.3 |
| 12 | −4 | 6 | 8 | 1.1 | 1.4 | 1.6 | 2.2 | 12 | 34 | 16 | 18 | 16.5 | 20.6 | 24.7 | 32.9 |
| 12 | −2 | 7 | 9 | 1.7 | 2.1 | 2.6 | 3.4 | 13 | −4 | 6 | 8 | 1.5 | 1.9 | 2.3 | 3.0 |
| 12 | 0 | 7 | 9 | 2.5 | 3.1 | 3.7 | 4.9 | 13 | −2 | 7 | 9 | 2.2 | 2.8 | 3.4 | 4.5 |
| 12 | 2 | 8 | 10 | 3.3 | 4.1 | 4.9 | 6.6 | 13 | 0 | 7 | 9 | 3.1 | 3.9 | 4.7 | 6.3 |
| 12 | 4 | 8 | 10 | 4.1 | 5.1 | 6.2 | 8.2 | 13 | 2 | 8 | 10 | 4.1 | 5.1 | 6.2 | 8.2 |
| 12 | 6 | 9 | 11 | 4.9 | 6.2 | 7.4 | 9.9 | 13 | 4 | 8 | 10 | 5.1 | 6.3 | 7.6 | 10.1 |
| 12 | 8 | 9 | 11 | 5.8 | 7.2 | 8.6 | 11.5 | 13 | 6 | 9 | 11 | 6.0 | 7.5 | 9.1 | 12.1 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | | *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 13 | 8 | 9 | 11 | 7.0 | 8.7 | 10.5 | 14.0 | 14 | 8 | 10 | 12 | 8.4 | 10.5 | 12.6 | 16.8 |
| 13 | 10 | 10 | 12 | 8.0 | 10.0 | 12.0 | 15.9 | 14 | 10 | 10 | 12 | 9.5 | 11.9 | 14.3 | 19.0 |
| 13 | 12 | 10 | 12 | 8.9 | 11.2 | 13.4 | 17.9 | 14 | 12 | 11 | 13 | 10.6 | 13.3 | 16.0 | 21.3 |
| 13 | 14 | 11 | 13 | 9.9 | 12.4 | 14.8 | 19.8 | 14 | 14 | 11 | 13 | 11.8 | 14.7 | 17.6 | 23.5 |
| 13 | 16 | 11 | 13 | 10.9 | 13.6 | 16.3 | 21.7 | 14 | 16 | 12 | 14 | 12.9 | 16.1 | 19.3 | 25.8 |
| 13 | 18 | 12 | 14 | 11.8 | 14.8 | 17.7 | 23.7 | 14 | 18 | 12 | 14 | 14.0 | 17.5 | 21.0 | 28.0 |
| 13 | 20 | 12 | 14 | 12.8 | 16.0 | 19.2 | 25.6 | 14 | 20 | 13 | 15 | 15.1 | 18.9 | 22.7 | 30.2 |
| 13 | 22 | 13 | 15 | 13.8 | 17.2 | 20.6 | 27.5 | 14 | 22 | 13 | 15 | 16.2 | 20.3 | 24.4 | 32.5 |
| 13 | 24 | 13 | 15 | 14.7 | 18.4 | 22.1 | 29.5 | 14 | 24 | 14 | 16 | 17.4 | 21.7 | 26.0 | 34.7 |
| 13 | 26 | 14 | 16 | 15.7 | 19.6 | 23.5 | 31.4 | 14 | 26 | 14 | 16 | 18.5 | 23.1 | 27.7 | 37.0 |
| 13 | 28 | 14 | 16 | 16.7 | 20.8 | 25.0 | 33.3 | 14 | 28 | 15 | 17 | 19.6 | 24.5 | 29.4 | 39.2 |
| 13 | 30 | 15 | 17 | 17.6 | 22.0 | 26.4 | 35.2 | 14 | 30 | 15 | 17 | 20.7 | 25.9 | 31.1 | 41.4 |
| 13 | 32 | 15 | 17 | 18.6 | 23.2 | 27.9 | 37.2 | 14 | 32 | 16 | 18 | 21.8 | 27.3 | 32.8 | 43.7 |
| 14 | −4 | 7 | 9 | 2.0 | 2.5 | 3.0 | 4.0 | 15 | −6 | 6 | 8 | 1.7 | 2.2 | 2.6 | 3.5 |
| 14 | −2 | 7 | 9 | 2.9 | 3.6 | 4.3 | 5.8 | 15 | −4 | 7 | 9 | 2.6 | 3.2 | 3.9 | 5.2 |
| 14 | 0 | 8 | 10 | 3.9 | 4.9 | 5.9 | 7.8 | 15 | −2 | 7 | 9 | 3.6 | 4.5 | 5.4 | 7.2 |
| 14 | 2 | 8 | 10 | 5.0 | 6.3 | 7.6 | 10.1 | 15 | 0 | 8 | 10 | 4.8 | 6.0 | 7.2 | 9.6 |
| 14 | 4 | 9 | 11 | 6.2 | 7.7 | 9.2 | 12.3 | 15 | 2 | 8 | 10 | 6.1 | 7.6 | 9.2 | 12.2 |
| 14 | 6 | 9 | 11 | 7.3 | 9.1 | 10.9 | 14.6 | 15 | 4 | 9 | 11 | 7.4 | 9.2 | 11.1 | 14.8 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | | *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 15 | 6 | 9 | 11 | 8.7 | 10.8 | 13.0 | 17.4 | 16 | 6 | 9 | 12 | 10.2 | 12.8 | 15.4 | 20.5 |
| 15 | 8 | 10 | 12 | 10.0 | 12.5 | 14.9 | 19.9 | 16 | 8 | 9 | 12 | 11.7 | 14.6 | 17.6 | 23.4 |
| 15 | 10 | 10 | 12 | 11.3 | 14.1 | 16.9 | 22.5 | 16 | 10 | 10 | 13 | 13.2 | 16.5 | 19.7 | 26.3 |
| 15 | 12 | 11 | 13 | 12.5 | 15.7 | 18.8 | 25.1 | 16 | 12 | 10 | 13 | 14.6 | 18.3 | 21.9 | 29.3 |
| 15 | 14 | 11 | 13 | 13.8 | 17.3 | 20.7 | 27.6 | 16 | 14 | 11 | 14 | 16.1 | 20.1 | 24.1 | 32.2 |
| 15 | 16 | 12 | 14 | 15.1 | 18.9 | 22.7 | 30.2 | 16 | 16 | 11 | 14 | 17.6 | 21.9 | 26.3 | 35.1 |
| 15 | 18 | 12 | 14 | 16.4 | 20.5 | 24.6 | 32.8 | 16 | 18 | 12 | 15 | 19.0 | 23.8 | 28.5 | 38.0 |
| 15 | 20 | 13 | 15 | 17.7 | 22.1 | 26.5 | 35.4 | 16 | 20 | 12 | 15 | 20.5 | 25.6 | 30.7 | 41.0 |
| 15 | 22 | 13 | 15 | 19.0 | 23.7 | 28.4 | 37.9 | 16 | 22 | 13 | 16 | 21.9 | 27.4 | 32.9 | 43.9 |
| 15 | 24 | 14 | 16 | 20.3 | 25.3 | 30.4 | 40.5 | 16 | 24 | 13 | 16 | 23.4 | 29.3 | 35.1 | 46.8 |
| 15 | 26 | 14 | 16 | 21.5 | 26.9 | 32.3 | 43.1 | 16 | 26 | 14 | 17 | 24.9 | 31.1 | 37.3 | 49.7 |
| 15 | 28 | 15 | 17 | 22.8 | 28.5 | 34.2 | 45.6 | 16 | 28 | 14 | 17 | 26.3 | 32.9 | 39.5 | 53.0 |
| 15 | 30 | 15 | 17 | 24.1 | 30.1 | 36.2 | 48.2 | 16 | 30 | 15 | 18 | 27.8 | 34.7 | 41.7 | 56.0 |
| 16 | −6 | 6 | 9 | 2.3 | 2.9 | 3.4 | 4.6 | 17 | −6 | 6 | 9 | 2.9 | 3.7 | 4.4 | 5.9 |
| 16 | −4 | 6 | 9 | 3.3 | 4.1 | 4.9 | 6.6 | 17 | −4 | 6 | 9 | 4.1 | 5.1 | 6.2 | 8.2 |
| 16 | −2 | 7 | 10 | 4.5 | 5.6 | 6.7 | 9.0 | 17 | −2 | 7 | 10 | 5.5 | 6.8 | 8.2 | 10.9 |
| 16 | 0 | 7 | 10 | 5.9 | 7.3 | 8.8 | 11.7 | 17 | 0 | 7 | 10 | 7.0 | 8.8 | 10.5 | 14.0 |
| 16 | 2 | 8 | 11 | 7.3 | 9.1 | 11.0 | 14.6 | 17 | 2 | 8 | 11 | 8.7 | 10.8 | 13.0 | 17.3 |
| 16 | 4 | 8 | 11 | 8.8 | 11.0 | 13.2 | 17.6 | 17 | 4 | 8 | 11 | 10.3 | 12.9 | 15.5 | 20.6 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | | *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 17 | 6 | 9 | 12 | 12.0 | 15.0 | 18.0 | 23.9 | 18 | 8 | 10 | 13 | 15.7 | 19.7 | 23.6 | 31.5 |
| 17 | 8 | 9 | 12 | 13.6 | 17.0 | 20.4 | 27.3 | 18 | 10 | 10 | 13 | 17.6 | 22.0 | 26.4 | 35.2 |
| 17 | 10 | 10 | 13 | 15.3 | 19.1 | 22.9 | 30.6 | 18 | 12 | 11 | 14 | 19.4 | 24.3 | 29.2 | 38.9 |
| 17 | 12 | 10 | 13 | 16.9 | 21.2 | 25.4 | 33.9 | 18 | 14 | 11 | 14 | 21.3 | 26.6 | 31.9 | 42.6 |
| 17 | 14 | 11 | 14 | 18.6 | 23.2 | 27.9 | 37.2 | 18 | 16 | 12 | 15 | 23.1 | 28.9 | 34.7 | 46.3 |
| 17 | 16 | 11 | 14 | 20.2 | 25.3 | 30.3 | 40.5 | 18 | 18 | 12 | 15 | 25.0 | 31.2 | 37.5 | 50.0 |
| 17 | 18 | 12 | 15 | 21.9 | 27.4 | 32.8 | 43.8 | 18 | 20 | 13 | 16 | 26.8 | 33.6 | 40.3 | 54.0 |
| 17 | 20 | 12 | 15 | 23.5 | 29.4 | 35.3 | 47.1 | 18 | 22 | 13 | 16 | 28.7 | 35.9 | 43.0 | 57.0 |
| 17 | 22 | 13 | 16 | 25.2 | 31.5 | 37.8 | 50.0 | 18 | 24 | 14 | 17 | 30.6 | 38.2 | 45.8 | 61.0 |
| 17 | 24 | 13 | 16 | 26.8 | 33.5 | 40.2 | 54.0 | 18 | 26 | 14 | 17 | 32.4 | 40.5 | 48.6 | 65.0 |
| 17 | 26 | 14 | 17 | 28.5 | 35.6 | 42.7 | 57.0 | 18 | 28 | 15 | 18 | 34.3 | 42.8 | 51.0 | 69.0 |
| 17 | 28 | 14 | 17 | 30.1 | 37.7 | 45.2 | 60.0 | 19 | −6 | 6 | 9 | 4.6 | 5.7 | 6.9 | 9.2 |
| 18 | −6 | 6 | 9 | 3.7 | 4.6 | 5.6 | 7.4 | 19 | −4 | 7 | 10 | 6.1 | 7.6 | 9.2 | 12.2 |
| 18 | −4 | 7 | 10 | 5.0 | 6.3 | 7.6 | 10.1 | 19 | −2 | 7 | 10 | 7.8 | 9.8 | 11.8 | 15.7 |
| 18 | −2 | 7 | 10 | 6.6 | 8.2 | 9.9 | 13.2 | 19 | 0 | 8 | 11 | 9.8 | 12.2 | 14.7 | 19.6 |
| 18 | 0 | 8 | 11 | 8.3 | 10.4 | 12.5 | 16.7 | 19 | 2 | 8 | 11 | 11.9 | 14.8 | 17.8 | 23.7 |
| 18 | 2 | 8 | 11 | 10.2 | 12.7 | 15.3 | 20.4 | 19 | 4 | 9 | 12 | 13.9 | 17.4 | 20.9 | 27.9 |
| 18 | 4 | 9 | 12 | 12.0 | 15.0 | 18.1 | 24.1 | 19 | 6 | 9 | 12 | 16.0 | 20.0 | 24.0 | 32.0 |
| 18 | 6 | 9 | 12 | 13.9 | 17.4 | 20.8 | 27.8 | 19 | 8 | 10 | 13 | 18.1 | 22.6 | 27.1 | 36.1 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | | $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 19 | 10 | 10 | 13 | 20.1 | 25.1 | 30.2 | 40.2 | 20 | 14 | 12 | 15 | 27.4 | 34.3 | 41.1 | 55.0 |
| 19 | 12 | 11 | 14 | 22.2 | 27.7 | 33.3 | 44.4 | 20 | 16 | 12 | 15 | 29.7 | 37.2 | 44.6 | 59.0 |
| 19 | 14 | 11 | 14 | 24.2 | 30.3 | 36.4 | 48.5 | 20 | 18 | 13 | 16 | 32.0 | 40.0 | 48.0 | 64.0 |
| 19 | 16 | 12 | 15 | 26.3 | 32.9 | 39.5 | 53.0 | 20 | 20 | 13 | 16 | 34.3 | 42.9 | 51.0 | 69.0 |
| 19 | 18 | 12 | 15 | 28.4 | 35.5 | 42.5 | 57.0 | 20 | 22 | 14 | 17 | 36.6 | 45.7 | 55.0 | 73.0 |
| 19 | 20 | 13 | 16 | 30.4 | 38.0 | 45.6 | 61.0 | 20 | 24 | 14 | 17 | 38.9 | 48.6 | 58.0 | 78.0 |
| 19 | 22 | 13 | 16 | 32.5 | 40.6 | 48.7 | 65.0 | 20 | 26 | 15 | 18 | 41.1 | 51.0 | 62.0 | 82.0 |
| 19 | 24 | 14 | 17 | 34.6 | 43.2 | 52.0 | 69.0 | 21 | −6 | 6 | 10 | 6.8 | 8.4 | 10.1 | 13.5 |
| 19 | 26 | 14 | 17 | 36.6 | 45.8 | 55.0 | 73.0 | 21 | −4 | 6 | 10 | 8.7 | 10.8 | 13.0 | 17.3 |
| 20 | −6 | 7 | 10 | 5.6 | 7.0 | 8.4 | 11.2 | 21 | −2 | 7 | 11 | 10.8 | 13.5 | 16.2 | 21.7 |
| 20 | −4 | 7 | 10 | 7.3 | 9.1 | 11.0 | 14.6 | 21 | 0 | 7 | 11 | 13.2 | 16.5 | 19.8 | 26.5 |
| 20 | −2 | 8 | 11 | 9.3 | 11.6 | 13.9 | 18.5 | 21 | 2 | 8 | 12 | 15.7 | 19.7 | 23.6 | 31.5 |
| 20 | 0 | 8 | 11 | 11.4 | 14.3 | 17.1 | 22.9 | 21 | 4 | 8 | 12 | 18.3 | 22.8 | 27.4 | 36.5 |
| 20 | 2 | 9 | 12 | 13.7 | 17.1 | 20.6 | 27.4 | 21 | 6 | 9 | 13 | 20.8 | 26.0 | 31.2 | 41.6 |
| 20 | 4 | 9 | 12 | 16.0 | 20.0 | 24.0 | 32.0 | 21 | 8 | 9 | 13 | 23.3 | 29.1 | 35.0 | 46.6 |
| 20 | 6 | 10 | 13 | 18.3 | 22.9 | 27.4 | 36.6 | 21 | 10 | 10 | 14 | 25.8 | 32.3 | 38.7 | 52.0 |
| 20 | 8 | 10 | 13 | 20.6 | 25.7 | 30.9 | 41.1 | 21 | 12 | 10 | 14 | 28.3 | 35.4 | 42.5 | 57.0 |
| 20 | 10 | 11 | 14 | 22.9 | 28.6 | 34.3 | 45.7 | 21 | 14 | 11 | 15 | 30.9 | 38.6 | 46.3 | 62.0 |
| 20 | 12 | 11 | 14 | 25.1 | 31.4 | 37.7 | 50.0 | 21 | 16 | 11 | 15 | 33.4 | 41.7 | 50.0 | 67.0 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | | $l$, feet. | $h$, feet. | Weight of plating. | | Section modulus $S$ for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 21 | 18 | 12 | 16 | 35.9 | 44.9 | 54.0 | 72.0 | 22 | 24 | 14 | 18 | 48.4 | 60.0 | 73.0 | 97.0 |
| 21 | 20 | 12 | 16 | 38.4 | 48.0 | 58.0 | 77.0 | 23 | −6 | 6 | 10 | 9.5 | 11.9 | 14.2 | 19.0 |
| 21 | 22 | 13 | 17 | 41.0 | 51.0 | 61.0 | 82.0 | 23 | −4 | 7 | 11 | 11.9 | 14.8 | 17.8 | 23.7 |
| 21 | 24 | 13 | 17 | 43.5 | 54.0 | 65.0 | 87.0 | 23 | −2 | 7 | 11 | 14.5 | 18.1 | 21.7 | 29.0 |
| 22 | −6 | 6 | 10 | 8.0 | 10.1 | 12.1 | 16.1 | 23 | 0 | 8 | 12 | 17.4 | 21.7 | 26.1 | 34.8 |
| 22 | −4 | 7 | 11 | 10.2 | 12.7 | 15.3 | 20.4 | 23 | 2 | 8 | 12 | 20.4 | 25.5 | 30.6 | 40.8 |
| 22 | −2 | 7 | 11 | 12.6 | 15.7 | 18.9 | 25.1 | 23 | 4 | 9 | 13 | 23.4 | 29.3 | 35.1 | 46.9 |
| 22 | 0 | 8 | 12 | 15.2 | 19.0 | 22.8 | 30.4 | 23 | 6 | 9 | 13 | 26.5 | 33.1 | 39.7 | 53.0 |
| 22 | 2 | 8 | 12 | 18.0 | 22.5 | 27.0 | 36.0 | 23 | 8 | 10 | 14 | 29.5 | 36.8 | 44.2 | 59.0 |
| 22 | 4 | 9 | 13 | 20.7 | 25.9 | 31.1 | 41.5 | 23 | 10 | 10 | 14 | 32.5 | 40.6 | 48.7 | 65.0 |
| 22 | 6 | 9 | 13 | 23.5 | 29.4 | 35.3 | 47.0 | 23 | 12 | 11 | 15 | 35.5 | 44.4 | 53.0 | 71.0 |
| 22 | 8 | 10 | 14 | 26.3 | 32.8 | 39.4 | 53.0 | 23 | 14 | 11 | 15 | 38.5 | 48.2 | 58.0 | 77.0 |
| 22 | 10 | 10 | 14 | 29.0 | 36.3 | 43.6 | 58.0 | 23 | 16 | 12 | 16 | 41.6 | 52.0 | 62.0 | 83.0 |
| 22 | 12 | 11 | 15 | 31.8 | 39.8 | 47.7 | 64.0 | 23 | 18 | 12 | 16 | 44.6 | 56.0 | 67.0 | 89.0 |
| 22 | 14 | 11 | 15 | 34.6 | 43.2 | 52.0 | 69.0 | 23 | 20 | 13 | 17 | 47.6 | 60.0 | 71.0 | 95.0 |
| 22 | 16 | 12 | 16 | 37.3 | 46.7 | 56.0 | 75.0 | 23 | 22 | 13 | 17 | 51.0 | 63.0 | 76.0 | 101.0 |
| 22 | 18 | 12 | 16 | 40.1 | 50.0 | 60.0 | 80.0 | 24 | −6 | 7 | 11 | 11.1 | 13.9 | 16.7 | 22.2 |
| 22 | 20 | 13 | 17 | 42.9 | 54.0 | 64.0 | 86.0 | 24 | −4 | 7 | 11 | 13.7 | 17.1 | 20.6 | 27.4 |
| 22 | 22 | 13 | 17 | 45.6 | 57.0 | 68.0 | 91.0 | 24 | −2 | 8 | 12 | 16.6 | 20.7 | 24.9 | 33.2 |

TABLE I.—Thickness of Bulkhead Plating and Section Modulus of Stiffeners—Continued.

| *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | | *l*, feet. | *h*, feet. | Weight of plating. | | Section modulus *S* for different spans. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3ft. | 4 ft. | | | Upper strake, lbs. | Lower strake, lbs. | 2 ft. | 2 ft. 6 in. | 3 ft. | 4 ft. |
| 24 | 0 | 8 | 12 | 19.7 | 24.7 | 29.6 | 39.5 | 25 | 10 | 11 | 15 | 40.2 | 50.0 | 60.0 | 80.0 |
| 24 | 2 | 9 | 13 | 23.0 | 28.8 | 34.6 | 46.1 | 25 | 12 | 11 | 15 | 43.8 | 55.0 | 66.0 | 88.0 |
| 24 | 4 | 9 | 13 | 26.3 | 32.9 | 39.5 | 53.0 | 25 | 14 | 12 | 16 | 47.3 | 59.0 | 71.0 | 95.0 |
| 24 | 6 | 10 | 14 | 29.6 | 37.0 | 44.4 | 59.0 | 25 | 16 | 12 | 16 | 51.0 | 64.0 | 76.0 | 102.0 |
| 24 | 8 | 10 | 14 | 32.9 | 41.1 | 49.4 | 66.0 | 25 | 18 | 13 | 17 | 54.0 | 68.0 | 82.0 | 109.0 |
| 24 | 10 | 11 | 15 | 36.2 | 45.3 | 54.0 | 72.0 | 25 | 20 | 13 | 17 | 58.0 | 73.0 | 87.0 | 116.0 |
| 24 | 12 | 11 | 15 | 39.5 | 49.4 | 59.0 | 79.0 | 26 | −6 | 7 | 11 | 14.9 | 18.6 | 22.3 | 29.7 |
| 24 | 14 | 12 | 16 | 42.8 | 53.0 | 64.0 | 86.0 | 26 | −4 | 8 | 12 | 18.0 | 22.5 | 27.0 | 36.0 |
| 24 | 16 | 12 | 16 | 46.1 | 58.0 | 69.0 | 92.0 | 26 | −2 | 8 | 12 | 21.4 | 26.7 | 32.1 | 42.8 |
| 24 | 18 | 13 | 17 | 49.4 | 62.0 | 74.0 | 99.0 | 26 | 0 | 9 | 13 | 25.1 | 31.4 | 37.7 | 50.0 |
| 24 | 20 | 13 | 17 | 53.0 | 66.0 | 79.0 | 105.0 | 26 | 2 | 9 | 13 | 29.0 | 36.2 | 43.5 | 58.0 |
| 24 | 22 | 14 | 18 | 56.0 | 70.0 | 84.0 | 112.0 | 26 | 4 | 10 | 14 | 32.8 | 41.0 | 49.3 | 66.0 |
| 25 | −6 | 7 | 11 | 12.9 | 16.1 | 19.3 | 25.8 | 26 | 6 | 10 | 14 | 36.7 | 45.9 | 55.0 | 73.0 |
| 25 | −4 | 7 | 11 | 15.8 | 19.7 | 23.6 | 31.5 | 26 | 8 | 11 | 15 | 40.6 | 51.0 | 61.0 | 81.0 |
| 25 | −2 | 8 | 12 | 18.9 | 23.6 | 28.3 | 37.8 | 26 | 10 | 11 | 15 | 44.4 | 56.0 | 67.0 | 89.0 |
| 25 | 0 | 8 | 12 | 22.3 | 27.9 | 33.5 | 44.6 | 26 | 12 | 12 | 16 | 48.3 | 60.0 | 72.0 | 97.0 |
| 25 | 2 | 9 | 13 | 25.9 | 32.4 | 38.8 | 52.0 | 26 | 14 | 12 | 16 | 52.0 | 65.0 | 78.0 | 104.0 |
| 25 | 4 | 9 | 13 | 29.5 | 36.8 | 44.2 | 59.0 | 26 | 16 | 13 | 17 | 56.0 | 70.0 | 84.0 | 112.0 |
| 25 | 6 | 10 | 14 | 33.0 | 41.3 | 49.5 | 66.0 | 26 | 18 | 13 | 17 | 60.0 | 75.0 | 90.0 | 120.0 |
| 25 | 8 | 10 | 14 | 36.6 | 45.8 | 55.0 | 73.0 | 26 | 20 | 14 | 18 | 64.0 | 80.0 | 96.0 | 127.0 |

# TABLE II.

## CARNEGIE STEEL COMPANY'S SHAPES.

I-BARS.

| Size. | Thickness of web. | Weight per foot run. | Dimensions of face plate. | Section modulus. | |
|---|---|---|---|---|---|
| | | | | Without face plate. | With face plate. |
| Inches. | Inch. | Pounds. | Inches. | Sq. in. × in. | Sq. in. × in. |
| 5×3.00×3.00 | .210 | 9.75 | 4×$\frac{5}{16}$ | 5.5 | 10.5 |
| 5×3.15×3.15 | .357 | 12.25 | 4×$\frac{3}{8}$ | 6.5 | 12.3 |
| 5×3.29×3.29 | .504 | 14.75 | 4×$\frac{7}{16}$ | 7.4 | 14.0 |
| 6×3.33×3.33 | .230 | 12.25 | 5×$\frac{3}{8}$ | 8.4 | 17.8 |
| 6×3.45×3.45 | .352 | 14.75 | 5×$\frac{7}{16}$ | 9.6 | 20.2 |
| 6×3.58×3.58 | .475 | 17.25 | 5×$\frac{1}{2}$ | 10.8 | 22.6 |
| 7×3.66×3.66 | .250 | 15.00 | 5×$\frac{3}{8}$ | 11.8 | 22.5 |
| 7×3.76×3.76 | .353 | 17.50 | 5×$\frac{7}{16}$ | 13.1 | 25.3 |
| 7×3.87×3.87 | .458 | 20.00 | 5×$\frac{1}{2}$ | 14.5 | 28.1 |
| 8×4.00×4.00 | .270 | 18.00 | 6×$\frac{3}{8}$ | 16.1 | 31.0 |
| 8×4.09×4.09 | .357 | 20.50 | 6×$\frac{7}{16}$ | 17.7 | 34.8 |
| 8×4.18×4.18 | .449 | 23.00 | 6×$\frac{1}{2}$ | 19.2 | 38.4 |
| 9×4.33×4.33 | .290 | 21.00 | 6×$\frac{3}{8}$ | 21.2 | 37.7 |
| 9×4.45×4.45 | .406 | 25.00 | 6×$\frac{7}{16}$ | 23.5 | 42.3 |
| 9×4.61×4.61 | .569 | 30.00 | 6×$\frac{1}{2}$ | 26.7 | 47.5 |
| 10×4.66×4.66 | .310 | 25.00 | 7×$\frac{3}{8}$ | 27.4 | 49.0 |
| 10×4.81×4.81 | .455 | 30.00 | 7×$\frac{7}{16}$ | 30.9 | 55.0 |
| 10×4.95×4.95 | .602 | 35.00 | 7×$\frac{1}{2}$ | 34.5 | 62.0 |
| 10×5.10×5.10 | .749 | 40.00 | 7×$\frac{9}{16}$ | 38.1 | 68.0 |
| 12×5.00×5.00 | .350 | 31.50 | 8×$\frac{3}{8}$ | 40.3 | 70.0 |
| 12×5.00×5.00 | .350 | 31.50 | 8×$\frac{7}{16}$ | 40.8 | 76.0 |
| 12×5.09×5.09 | .436 | 35.00 | 8×$\frac{7}{16}$ | 43.5 | 77.0 |
| 12×5.09×5.09 | .436 | 35.00 | 8×$\frac{1}{2}$ | 44.0 | 83.0 |
| 12×5.25×5.25 | .460 | 40.00 | 8×$\frac{1}{2}$ | 51.0 | 89.0 |
| 12×5.25×5.25 | .460 | 40.00 | 8×$\frac{9}{16}$ | 51.0 | 95.0 |

## TABLE II.—CARNEGIE STEEL COMPANY'S SHAPES—Continued.

I-BARS—Continued.

| Size. | Thickness of web. | Weight per foot run. | Dimensions of face plate. | Section modulus. | |
|---|---|---|---|---|---|
| | | | | Without face plate. | With face plate. |
| Inches. | Inch. | Pounds. | Inches. | Sq. in. × in. | Sq. in. × in. |
| 12×5.37×5.37 | .576 | 45.00 | 8×$\frac{9}{16}$ | 55.0 | 98.0 |
| 12×5.37×5.37 | .576 | 45.00 | 8×$\frac{5}{8}$ | 56.0 | 103.0 |
| 12×5.49×5.49 | .699 | 50.00 | 8×$\frac{5}{8}$ | 59.0 | 106.0 |
| 12×5.49×5.49 | .699 | 50.00 | 8×$\frac{11}{16}$ | 60.0 | 111.0 |
| 15×5.50×5.50 | .410 | 42.00 | 8×$\frac{7}{16}$ | 66.0 | 108.0 |
| 15×5.55×5.55 | .460 | 45.00 | 8×$\frac{1}{2}$ | 69.0 | 117.0 |
| 15×5.65×5.65 | .558 | 50.00 | 8×$\frac{9}{16}$ | 74.0 | 128.0 |
| 15×5.75×5.75 | .656 | 55.00 | 8×$\frac{5}{8}$ | 80.0 | 138.0 |
| 15×6.00×6.00 | .590 | 60.00 | 8×$\frac{9}{16}$ | 91.0 | 143.0 |
| 15×6.10×6.10 | .686 | 65.00 | 8×$\frac{5}{8}$ | 96.0 | 153.0 |
| 15×6.19×6.19 | .784 | 70.00 | 8×$\frac{11}{16}$ | 102.0 | 164.0 |

NOTE: A strip of bulkhead plating of the same sectional area as the face plate is assumed to work with the stiffeners.

## TABLE II.—CARNEGIE STEEL COMPANY'S SHAPES.—Continued.

Z-BARS.

| Without reverse bar. | | | | With reverse bar. | | |
|---|---|---|---|---|---|---|
| Size. | Thickness of metal. | Weight per foot run. | Section modulus. | Size of reverse bar. | Weight per foot run. | Section modulus. |
| Inches. | Inch. | Pounds. | Sq. in. × in. | Inches. | Pounds. | Sq. in. × in. |
| 4×3 1/16×3 1/16 | 1/4 | 8.2 | 4.2 | ..... | ..... | ..... |
| 4×3 1/16×3 1/16 | 7/16 | 13.8 | 6.3 | ..... | ..... | ..... |
| 4×3 1/16×3 1/16 | 5/8 | 18.9 | 7.8 | ..... | ..... | ..... |
| 5×3 1/4 ×3 1/4 | 5/16 | 11.6 | 6.1 | ..... | ..... | ..... |
| 5×3 1/4 ×3 1/4 | 1/2 | 17.9 | 8.7 | ..... | ..... | ..... |
| 5×3 1/4 ×3 1/4 | 11/16 | 23.7 | 10.7 | ..... | ..... | ..... |
| 6×3 1/2 ×3 1/2 | 3/8 | 15.6 | 9.5 | 3×3 | 7.2 | 14.1 |
| 6×3 1/2 ×3 1/2 | 9/16 | 22.7 | 12.9 | 3×3 | 7.2 | 17.0 |
| 6×3 1/2 ×3 1/2 | 3/4 | 29.3 | 15.5 | 3×3 | 7.2 | 19.4 |

NOTE: A strip of bulkhead plating of 1.25 sq. in. area is assumed to work with the stiffeners.

SHIPBUILDING CHANNELS.

| Size. | Thickness of web. | Weight per foot run. | Section modulus. | |
|---|---|---|---|---|
| | | | Without face plate. | With face plate. |
| Inches. | Inch. | Pounds. | Sq. in. × in. | Sq. in. × in. |
| 6×3.50×3.50 | .35 | 15.0 | 9.5 | 15.4 |
| 7×3.45×3.45 | .45 | 20.9 | 14.7 | 23.3 |
| 8×3.50×3.50 | .50 | 23.8 | 18.3 | 28.2 |
| 9×3.80×3.80 | .45 | 28.6 | 26.4 | 42.4 |
| 10×3.38×3.38 | .38 | 21.8 | 20.8 | 31.7 |
| 10×3.50×3.50 | .50 | 27.2 | 25.1 | 37.4 |

NOTE: A strip of bulkhead plating of sectional area equal to that of the flange attached to the bulkhead is assumed to work with the stiffeners. Face plates are assumed to have the same width and thickness as the flange.

# TABLE II.

## BRITISH STANDARD SECTIONS.

### LLOYD'S RULES 1909–10.

CHANNELS.

| Correct standard profile. | | | | | Maximum web thickness. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Size. | Thickness. | | Section modulus. | | Size. | Thickness. | | Section modulus. | |
| | Web. | Flange. | Without face plate. | With face plate. | | Web. | Flange. | Without face plate. | With face plate. |
| Inches. | Inch. | Inch. | Sq.in.×in. | Sq.in.×in. | Inches. | Inch. | Inch. | Sq.in.×in. | Sq.in.×in. |
| 6.0×3.0×3.0 | .375 | .475 | 10.0 | 16.0 | 6.0×3.2×3.2 | .575 | .475 | 11.5 | 17.6 |
| 6.0×3.5×3.5 | .375 | .475 | 11.3 | 18.5 | 6.0×3.5×3.7 | .575 | .475 | 12.8 | 20.1 |
| 7.0×3.0×3.0 | .375 | .475 | 12.3 | 19.4 | 7.0×3.2×3.2 | .575 | .475 | 14.3 | 21.4 |
| 7.0×3.5×3.5 | .400 | .500 | 14.3 | 23.1 | 7.0×3.7×3.7 | .600 | .500 | 16.4 | 25.3 |
| 7.5×3.0×3.0 | .400 | .500 | 14.1 | 23.5 | 7.5×3.2×3.2 | .600 | .500 | 16.5 | 26.1 |
| 7.5×3.5×3.5 | .400 | .500 | 15.9 | 25.4 | 7.5×3.7×3.7 | .600 | .500 | 18.3 | 27.8 |
| 8.0×3.0×3.0 | .400 | .500 | 15.0 | 23.5 | 8.0×3.2×3.2 | .600 | .500 | 18.1 | 26.7 |
| 8.0×3.5×3.5 | .425 | .525 | 18.2 | 28.7 | 8.0×3.7×3.7 | .625 | .525 | 20.9 | 31.4 |
| 8.0×4.0×4.0 | .450 | .550 | 21.0 | 33.8 | 8.0×4.2×4.2 | .650 | .550 | 23.7 | 36.6 |
| 8.5×3.0×3.0 | .425 | .525 | 17.6 | 27.0 | 8.5×3.2×3.2 | .625 | .525 | 20.5 | 30.0 |
| 8.5×3.5×3.5 | .450 | .550 | 20.3 | 32.1 | 8.5×3.7×3.7 | .650 | .550 | 23.3 | 35.1 |
| 9.0×3.5×3.5 | .450 | .550 | 22.2 | 32.5 | 9.0×3.7×3.7 | .650 | .550 | 25.6 | 38.1 |
| 9.0×4.0×4.0 | .475 | .575 | 23.4 | 38.6 | 9.0×4.2×4.2 | .675 | .575 | 26.8 | 42.1 |
| 9.5×3.5×3.5 | .450 | .550 | 23.9 | 37.1 | 9.5×3.7×3.7 | .650 | .550 | 27.6 | 40.9 |
| 10.0×3.5×3.5 | .475 | .575 | 26.8 | 41.1 | 10.0×3.7×3.7 | .675 | .575 | 30.9 | 45.3 |
| 10.0×4.0×4.0 | .475 | .575 | 29.6 | 46.3 | 10.0×4.2×4.2 | .675 | .575 | 33.8 | 50.5 |
| 10.5×3.5×3.5 | .475 | .575 | 28.7 | 43.7 | 10.5×3.7×3.7 | .675 | .575 | 33.2 | 48.3 |
| 11.0×3.5×3.5 | .475 | .575 | 30.6 | 46.4 | 11.0×3.7×3.7 | .675 | .575 | 35.6 | 51.0 |
| 11.0×4.0×4.0 | .500 | .600 | 35.2 | 54.0 | 11.0×4.2×4.2 | .700 | .600 | 40.1 | 59.0 |
| 11.5×3.5×3.5 | .500 | .600 | 34.0 | 51.0 | 11.5×3.7×3.7 | .700 | .600 | 39.3 | 56.0 |
| 12.0×3.5×3.5 | .500 | .600 | 36.1 | 54.0 | 12.0×3.7×3.7 | .700 | .600 | 41.9 | 60.0 |
| 12.0×4.0×4.0 | .525 | .625 | 41.2 | 63.0 | 12.0×4.2×4.2 | .725 | .625 | 47.1 | 68.0 |

## TABLE II.—BRITISH STANDARD SECTIONS.—Continued.

### LLOYD'S RULES 1909–10.

### BULB ANGLES.

| Correct standard profile. | | | | Maximum web thickness. | | | |
|---|---|---|---|---|---|---|---|
| Size. | Thickness. | | Section modulus. | Size. | Thickness. | | Section modulus. |
| | Web. | Flange. | | | Web. | Flange. | |
| Inches. | Inch. | Inch. | Sq.in.×in. | Inches. | Inch. | Inch. | Sq.in.×in. |
| 5.5×3.0 | .350 | .350 | 4.8 | 5.5×3.2 | .550 | .450 | 6.6 |
| 6.0×3.0 | .375 | .375 | 5.8 | 6.0×3.2 | .575 | .475 | 8.0 |
| 6.5×3.0 | .375 | .375 | 6.8 | 6.5×3.2 | .575 | .475 | 9.2 |
| 6.5×3.5 | .400 | .400 | 7.7 | 6.5×3.7 | .600 | .500 | 9.8 |
| 7.0×3.0 | .400 | .400 | 8.4 | 7.0×3.2 | .600 | .500 | 11.1 |
| 7.0×3.5 | .425 | .425 | 8.9 | 7.0×3.7 | .625 | .525 | 11.8 |
| 7.5×3.0 | .425 | .425 | 10.0 | 7.5×3.2 | .625 | .525 | 13.5 |
| 7.5×3.5 | .425 | .425 | 10.5 | 7.5×3.7 | .625 | .525 | 13.7 |
| 8.0×3.0 | .425 | .425 | 11.6 | 8.0×3.2 | .625 | .525 | 14.9 |
| 8.0×3.5 | .450 | .450 | 12.2 | 8.0×3.7 | .650 | .550 | 15.8 |
| 8.5×3.0 | .450 | .450 | 13.8 | 8.5×3.2 | .650 | .550 | 17.3 |
| 8.5×3.5 | .475 | .475 | 14.4 | 8.5×3.7 | .675 | .575 | 18.5 |
| 9.0×3.0 | .475 | .475 | 15.6 | 9.0×3.2 | .675 | .575 | 20.5 |
| 9.0×3.5 | .475 | .475 | 16.2 | 9.0×3.7 | .675 | .575 | 20.5 |
| 9.5×3.5 | .500 | .500 | 19.0 | 9.5×3.7 | .700 | .600 | 23.7 |
| 10.0×3.5 | .525 | .525 | 21.5 | 10.0×3.7 | .725 | .625 | 27.0 |
| 10.5×3.5 | .550 | .550 | 24.6 | 10.5×3.7 | .750 | .650 | 31.3 |
| 11.0×3.5 | .550 | .550 | 26.7 | 11.0×3.7 | .750 | .650 | 33.4 |
| 11.5×3.5 | .600 | .600 | 31.9 | 11.5×3.7 | .800 | .700 | 39.0 |
| 12.0×4.0 | .600 | .600 | 35.3 | 12.0×4.2 | .800 | .700 | 42.8 |

## TABLE II.—BRITISH STANDARD SECTIONS—Continued.

### LLOYD'S RULES 1909–10.

COMMON ANGLES.

| Size. | Minimum thickness. | | Maximum thickness. | |
|---|---|---|---|---|
| | Thickness. | Section modulus. | Thickness. | Section modulus. |
| Inches. | Inch. | Sq. in. × in. | Inch. | Sq. in. × in. |
| 3.0×2.0 | .250 | .65 | .375 | 1.0 |
| 3.0×2.5 | .250 | .68 | .375 | 1.0 |
| 3.0×3.0 | .250 | .69 | .375 | 1.1 |
| 3.5×3.5 | .250 | .89 | .375 | 1.4 |
| 3.5×3.0 | .250 | .92 | .375 | 1.4 |
| 4.0×2.5 | .250 | 1.2 | .375 | 1.7 |
| 4.0×3.0 | .250 | 1.2 | .425 | 2.0 |
| 4.0×4.0 | .300 | 1.5 | .425 | 2.1 |
| 4.5×3.0 | .300 | 1.8 | .425 | 2.5 |
| 5.0×3.0 | .300 | 2.2 | .425 | 3.0 |
| 5.0×3.5 | .375 | 2.7 | .450 | 3.3 |
| 5.5×3.0 | .375 | 3.2 | .500 | 4.3 |
| 5.5×3.5 | .375 | 3.3 | .500 | 4.4 |

NOTE: In all cases [channels, bulbs, and angles], a strip of bulkhead plating of sectional area equal to that of the flange attached to the bulkhead, has been included in calculating the section modulus. Face plates are assumed to have the same width and thickness as the flanges to which they are attached.

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## DISCUSSION.

PROFESSOR CECIL H. PEABODY, *Member of Council:*—I had been hoping that some other member of the Society would discuss this paper of my colleague, Professor Hovgaard. There are some complimentary things that should be said concerning it that might come more gracefully from another, but perhaps I may be allowed

to say that we are to be congratulated on receiving a paper of so much importance and value.

I want to ask a question concerning a statement in the middle of page 91 to the effect that "In practically all cases the observed curve of deflection of the stiffeners, tests Nos. 1 to 6, corresponded fairly with the curve calculated under the assumption that the stiffeners were fairly supported at the apices of the brackets, etc." I wish to ask whether, in Professor Hovgaard's opinion, this may not be in part due to the fact that the stiffeners are not adequately secured at the neutral axis, because longitudinal slipping would produce an effect like that due to insufficient fastening of the ends of the stiffeners.

I desire, not as a criticism of this paper, but on general principles, to object to the use of the word "stiffeners" in connection with a discussion of the strength of bulkheads. Though I appreciate that there is difficulty in changing an accepted technical name, in this case I believe the use of the term "stiffeners" has led to losses of ships that might now be afloat had the designers and inspectors of those ships appreciated what this paper shows, namely, that the framing of the bulkhead is in a sense the bulkhead; the plating is only a water-excluding membrane. The use of the word like "stiffeners" infers that the plating of the bulkhead should be capable of excluding water and that it needs only stiffening to enable it to do so.

PROFESSOR HOVGAARD:—In answer to Professor Peabody's question I would say that I consider the fact that the double stiffeners behaved as if free to turn about the apices of their brackets as largely accidental, and without any deeper significance. It simply shows that stiffeners so constructed deflect more than might be expected if regard is had to their bracketing, and it shows in particular, that such stiffeners are less efficient than single stiffeners. If the riveting along the neutral axis had been more efficient, if, for instance, there had been two closely spaced lines of rivets connecting the flanges on each side of the bulkhead instead of one openly spaced line, the double stiffeners would probably have shown much less deflection and perhaps have behaved as did the single stiffeners. I do not, therefore, propose to base any rule or general conclusion on the experience with double stiffeners other than that such stiffeners should not be employed except where unavoidable, and that they should then have a better connection along the neutral axis.

THE PRESIDENT:—Is there any further discussion? If not, I will express in your behalf our thanks to Professor Hovgaard for a very interesting paper and we will pass to the reading of the next paper, entitled, "Coaling Warships from Colliers," by Mr. Spencer Miller, Member.

# COALING WARSHIPS FROM COLLIERS IN HARBOR.

By Spencer Miller, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

Commander A. P. Niblack, U. S. N., said before this Society in 1893:—

"Coal supply and rapid coaling are very important factors in efficiency, not only in an emergency but in time of peace, for the time spent in coaling ship is time wasted."*

One of the United States colliers (purchased during the Spanish-American war) discharged with its own gear from its four hatches 1,200 tons of coal in ten hours, 120 tons per hour or 30 tons per hour per hatch. About 100 men were required to fill the coal bags in the hold. For a single hour 50 tons of coal per hatch may be discharged by such means.

In contrast to this the U. S. Navy collier Hector discharged 190 tons of coal from one hatch in one hour, employing a self-filling bucket operated by two men. This means a great saving in manual labor as well as a saving of time. The importance of reducing the labor of coaling in time of war is apparent to everybody.

Our (United States) Navy Department began a few years ago to build colliers from their own designs or prescribed characteristics. The first two were the fleet colliers Vestal and Prometheus, both 16-knot ships, carrying 6,400 tons of coal each. Next were the Mars, Vulcan and Hector, sister ships, with 12 knots speed and 7,200 tons carrying capacity. The colliers Cyclops and Neptune, now under construction, will have 14 knots speed and carry 12,500 tons of coal each. All of these colliers, excepting the Cyclops, carry a novel form of coal-discharging gear known as the Marine Transfer. The Cyclops will discharge its coal by self-filling buckets but with a different operating system not described in this paper.

## THE MARINE TRANSFER ON THE COLLIERS VESTAL AND PROMETHEUS.

The collier Vestal (Figs. 1, 2 and 3, Plates 33 and 34) was built at the New York Navy Yard. The Prometheus, a sister ship, was built at the Mare Island Navy Yard. Each ship has eight hatches. Between each pair of hatches is a tall, vertical spar carrying four steel booms for the Marine Transfer and two for other service. Grouped about the base of each mast

*"Coal Bunkers and Coaling Ships."

on deck in a very contracted space are four specially designed winches, each provided with two independent metallic friction drums. The winches have double $8\frac{1}{4}$-inch by 10-inch cylinders. One man controls each winch, having two friction thrust pump handle levers in his hands and steam under foot. Stretched between the spars and high above the deck is a stay of large dimensions. This stay supports a double block over the center of each hatch. The hoisting rope leading from one drum of one winch leads aloft and over one of the pulleys of these double blocks and then drops vertically into the hold.

When the Marine Transfer is set up, two booms are outstretched and fixed by vangs on opposite sides of the ship and so disposed that a line drawn from their ends passes directly over the center of the hatch. To the ends of these booms pulley blocks are attached. To handle bags of coal three lines are used and two winches. One line is used to hoist the bags vertically from the hold. The other two lines lead in opposite directions to pulleys at the ends of the outstretched booms and back to a swinging block surrounding the hoisting rope. These two lines swing the load to and from the ship alongside. The hoisting line swings pendulum-like from the pulley block supported high above the center of the hatch. This line leads through a floating trolley or swinging block provided with large pulleys. This swinging block is hauled both ways by lines known as the inhaul and the outhaul. These lines are operated by the two drums of the winch known as the swinging winch. The weight of the swinging block is counterbalanced by adding a line (pendulum rope) to the swinging block and leading it aloft to the double block, thence to a pulley near the mast and downward to a weight suspended on its end. This weight runs on a standing rope as a guide (Plate 35).

### OPERATING A SELF-FILLING BUCKET.

In operating a self-filling or clamshell bucket a fourth line is added parallel to the hoisting line and operated by the second drum of the hoisting winch. This line is employed in closing the bucket. The operation is as follows:—

Suppose the bucket to be open on the coal in the hold.

1. By hauling in with one drum the bucket is closed, grabbing a load of coal.

2. By winding in both bucket lines the bucket is hoisted.

3. When the bucket is clear of the hatch it is swung outboard by hauling in on the outhaul rope and paying out (at the same speed) the inhaul rope.

4. Holding the bucket by the holding rope and paying out the closing rope the bucket empties its load.

5. Winding in on the inhaul rope and paying out on the outhaul rope the bucket is caused to swing back over the hatch.

6. Lowering or paying out the bucket lines lowers the bucket until it strikes the coal and the cycle is complete.

This cycle has been accomplished in an average of twenty-one seconds for an hour, although frequently single-bucket loads have been filled, discharged and returned in fifteen seconds.

### THE MARINE TRANSFER ON THE COLLIERS MARS, VULCAN AND HECTOR.

The colliers Mars, Vulcan and Hector were built by the Maryland Steel Company under one contract and are similar in all respects. Each ship has ten hatches. Between each pair of hatches are a pair of vertical king posts (Figs. 5 and 6, Plate 36). Each king post carries two steel booms. Between the king posts are four winches, being duplicates of those on the colliers Vestal and Prometheus (Fig. 7, Plate 37). The king posts are short; in fact, too short. When operating the Marine Transfer both booms are fixed. One supports the double swiveled and hinged block (Fig. 9, Plate 37) directly over the center of the hatch. The other is fixed outboard on the side where the coal is to be delivered. The inhaul pulley, which on the Vestal is placed on a boom end, is attached to the rail of the collier. The pendulum rope and counterpoise are omitted.

The masts and booms on these three colliers are cheaper than on the Vestal and Prometheus, but they are less favorable to the operation of the Marine Transfer. These colliers have wide hatches and a far greater amount of coal can be taken out of them with the clamshell bucket before trimming is necessary than is possible on the Vestal. The operation of the bucket is practically the same on all the colliers. The strain on the rope drawing the bucket outboard on the Mars is greater than the strain on the hoisting rope. This is because the king posts are low and because the point of suspension of the double block is low. It is of the greatest importance in designing ships to carry Marine Transfers that the most careful consideration be given to the strains developed. After the strains are computed for a quiescent load a factor of safety of from eight to ten should be employed. The arrangement of masts and booms on the collier Vestal is preferred by the writer to the arrangement on the Mars.

On the colliers Mars, Vulcan and Hector, fully loaded and with masts and booms as originally provided, the clamshell bucket clears the deck of war-

ships if not more than 20 feet above the water-line. Some of these masts have been raised about 8 feet which should mean that the clamshell bucket can clear the deck of a warship 28 feet above the water-line. As the collier discharges and rises the clearance gradually increases about 12 feet. When the masts were raised the booms were raised with them. This is an improvement. The point of suspension of the double block is carried higher and this reduces the strains developed when hauling the bucket outboard. To further reduce the strains on the masts and rigging the size of the clamshell bucket has been reduced. The first clamshell buckets carried 2,600 pounds of coal each and weighed 4,000 pounds, 6,600 pounds total, while the new ones carry 1,600 pounds each and weigh 2,600 pounds, 4,200 pounds total.

In the official coaling trials discharging into a barge and using the large bucket—

The Mars handled 137 bucket-loads, aggregating 117 tons.

The Vulcan handled* 155 bucket-loads, aggregating 180 tons.

The Hector handled 175 bucket-loads, aggregating 190 tons.

Ordinary seamen on board these colliers were drilled to operate the Marine Transfers with the clamshell buckets, from which it has been established that two fairly intelligent men require about eight hours to become sufficiently proficient to be capable of discharging 100 tons of coal per hour per hatch. One hundred and ninety tons of coal per hour per hatch can be discharged at any time with winchmen of sufficient skill and practise.

It is worthy of note that on the collier Vulcan, Captain Merithew commanding, after it had been in commission a few months and using the small three-quarter-ton bucket, two men discharged 95 tons of coal per hour. This would require about 133 bucket loads per hour, or one round trip every twenty-seven seconds.

## OPPOSITION TO USE OF CLAMSHELL BUCKETS.

When these colliers were first put into commission there was considerable opposition to the use of the clamshell buckets. It was feared the bucket would damage the deck or superstructure of the warship. The bucket always swings in the same plane. If it is going to hit anything it will hit it in the same spot each time. That spot can be protected by fenders, planks or suspended bags of coal. Planks laid on the deck will prevent the bucket from damaging the deck.

*See appendix for the exact time that each bucket-load was delivered and the time for each round trip.

## COALING THE U. S. S. MICHIGAN.

Plates 38 and 39 are half-tone photographs showing the U. S. collier Vestal coaling the U. S. S. Michigan, Capt. N. R. Usher, U. S. Navy, commanding. The Michigan has large coaling skylights (Plate 39), leading directly to the main deck level and through which coal can be poured for a time at the rate of 150 tons per hour. The coal on the main deck is shovelled into chutes leading to the bunkers. The photographs also show one of the buckets delivering coal to a pile (Plate 38), directly on the ship's deck. This pile of coal is surrounded by men with shovels. The pile being large, these men continue their work while the clamshell bucket delivers coal to the apex of the pile. Shovelling coal on deck where the shovel follows a plank is much more rapid than shovelling on top of the coal in the hold. Then again, baskets or trucks can be used. The baskets will stand alone and men are not required to hold them while being filled. Baskets holding about 45 pounds are carried with little fatigue. If bags were to be filled one man would do the shovelling while two other men held the bag, and the men would be in each other's way.

## COALING A TORPEDO-BOAT DESTROYER.

One of the most striking illustrations of the value of increased rate of discharge and reduction in labor is found in a recent coaling of a torpedo-boat destroyer. The destroyer was of the Flusser type. It received coal from the clamshell buckets of the collier Vestal. This boat took on 40 tons of coal in seventeen minutes, which is at the rate of 141 tons of coal per hour. Only two men were employed. On the destroyer two coal hatches (abreast the two after stacks) were removed. The clamshell bucket delivered its coal on the deck amidships, where it poured directly through both hatches and filled bunkers on both sides of the ship at the same time. Fully 70 per cent. of the coal flowed directly into the bunkers.

If a torpedo-boat destroyer can take on coal at one point at the rate of 141 tons per hour, battleships and cruisers can do as much. The battleship Virginia received and stowed 550 tons of coal per hour for a short time at a coaling station. When coaling from the Vestal only four or five hatches can serve a battleship at the same time, hence, about 500 to 600 tons is about all that will be delivered. It therefore appears that the maximum receiving capacity of the ship almost corresponds to the capacity of Marine Transfers available at one time.

### COALING THE PANTHER.

Photographic half-tones, (Plates 40, 41 and 42), give an excellent illustration of the employment of the clamshell bucket on the collier Mars delivering coal in bulk to the repair ship Panther. In this it will be observed (Plate 40) two men are required to operate the bucket. They can see the bucket in all of its positions while filling, hoisting and swinging outboard and discharging. The clamshell bucket in Plate 42 is shown delivering coal directly to the hopper wagons on the repair ship Panther. These hopper wagons were not purchased with reference to receiving coal from clamshell buckets, but it indicates an improvement in coaling methods. A larger hopper wagon to be carried on the collier or a collapsible truck would be better. Either would save the labor of hand shovelling.

### COALING TWO BATTLESHIPS AT ONCE.

The colliers Mars, Vulcan and Hector have ten large hatches and ten Marine Transfers which, if worked simultaneously, will discharge 1,000 tons of coal per hour. This capacity is sufficient to coal two battleships at once, giving each 500 tons of coal per hour as long as they can receive it. The last of the coaling must necessarily be slower.

Two battleships, one of them commanded by the late Admiral Converse, U. S. Navy, were coaled by a collier lying between them in smooth water off the coast of Porto Rico during the Spanish-American war. The circumstances justified the risk involved in placing a collier between two heavy battleships. In time of war our new colliers are quite likely to be called upon to perform similar duty.

### COAL DUST.

It was expected that coaling with clamshell buckets would be a much more dusty operation than coaling with bags. This, however, has not been found to be the case and it has been claimed by naval officers that coaling with clamshell buckets is less dusty than coaling with bags. The question, however, of more or less dust is hardly one which should be offered as an excuse for not taking advantage of the increased capacity and the reduction of labor force.

### A COLLIER COALING ANOTHER COLLIER.

A large fleet of United States battleships in a harbor in time of war would naturally have several of these new colliers in attendance. An

order from the Department to "coal and sail immediately" would probably result in the employment of every available collier to coal the battleships. When the battleships have coaled, however, it might still be desirable to have some of these colliers accompany the fleet. At this time, however, the colliers would be all partially empty. With the use of the rapid self-discharging appliances capable of discharging 1,000 tons per hour a few of the colliers could discharge their remaining coal to the colliers desired by the fleet. In this way, with a minimum delay of the fleet and with a few men employed, the colliers can accompany the fleet with full loads of coal. The empty ones can return to be refilled. Thus it may be observed that exigencies may arise in which the efficiency of the fleet as a whole might depend entirely on the efficiency of the collier's coal-discharging equipment.

## THE FATIGUE OF THE MEN.

To coal a battleship at a rate of 500 tons per hour using the old-fashioned "Yard and Stay" method with bags would require on the collier alone not less than 350 men from the battleship. If the work of 350 men in the hold can be done with 10 men, then 340 men will be saved from fatigue. Furthermore, the 340 men would lighten the labors of those on the battleship. This question of the fatigue of the men may have no value whatsoever in times of peace but may be of the utmost importance in times of war.

The British Admiralty has spent and is spending a vast amount of money in order to find a method of filling coal bags by mechanical appliances to save manual labor. An admiral with a fleet of battleships, in time of war, entering a harbor to take on coal before a fight, would welcome any improvement which would keep the crew in proper condition for the impending action. Again, suppose the men had spent the night before on deck ready for threatened attack from torpedo boats, they should rest, not coal ship.

## MODIFICATIONS OF THE MARINE TRANSFER.

First Officer Shurtleff, an old deep-sea sailor on the collier Vestal, has found two interesting modifications in the employment of the Marine Transfer which illustrate its flexibility. He has found that he can reach parts of the battleship better by detaching the outboard swinging rope pulley from the boom and attaching it to the battleship. He can reach farther with the coal bucket or coal bags in this way. Amidship coal

hatches might in this way be reached, but to do this a high point of suspension is required for the double blocks secured above the collier's hatch. This is practicable on the colliers Vestal and Prometheus.

Another modification discovered by Shurtleff was in delivering coal from the Vestal's hatch No. 7 (which at the time was well filled with coal) to a point on the battleship opposite hatch No. 6, which at the time was empty. The outboard boom of No. 7 hatch and the inboard boom of No. 6 were employed to support the pulleys for swinging the bucket; the swinging rope then passed on a diagonal line over hatch No. 7 and delivered coal to a position on the battleship opposite hatch No. 6.

### YARD AND STAY.

All of these colliers can employ the "Yard and Stay" method if desired. With the "Yard and Stay" it is impossible to use clamshell buckets. On these colliers the superiority of the Marine Transfer over the "Yard and Stay" for handling coal bags has been established. The Marine Transfer should always be used when bags are handled because the practise the men get may be availed of in operating with clamshell buckets. In the first instance three ropes are employed and in the latter four; otherwise the systems are the same.

The "Yard and Stay" method is effective if operated slowly. To operate it rapidly results in confusion and danger. With the superior control of the load with the Marine Transfer, higher speeds both of hoisting and swinging are permissible. A load every twenty seconds has been accomplished. The swinging ropes of the Marine Transfer are up clear of the hatch coamings and do not chafe. With the "Yard and Stay" one rope is sure to chafe over the hatch coamings. Winchmen who have learned the use of the Marine Transfer prefer it to the "Yard and Stay." This is the experience on these colliers. Another advantage in employing it is that the clamshell may be added or removed with but a few moments' delay if circumstances so demand.

### LABOR CONDITIONS.

These five colliers were completely equipped with the Marine Transfer before one was placed in commission. Then it was discovered that common, dollar-a-day seamen were expected to operate the winches. Some show an aptitude for operating these winches where others do not. Some are only too anxious to learn to operate the Marine Transfer, for when they have mastered the art, which they have learned at the expense of the

United States Government, they can leave and be employed on shore coal towers at three times the pay. For instance, the U. S. Collier Vestal had been in commission one year on or about October 20, 1910. At this date it was full and ready to sail to coal our battleship fleet in English or French ports. The men had completed their first year of enlistment. Every man who had become an accomplished winchman left the ship. A green crew was taken on board, not one of whom understood the new winches. If the collier arrives in port a few days in advance of the fleet it will have time to teach these seamen to handle the Marine Transfer.

It would seem reasonable to offer some incentive for seamen to become accomplished winchmen and, when accomplished, to be retained. One suggestion is that when winchmen become proficient they might be paid one or two cents extra for each ton of coal discharged by them. Perhaps, too, captains of warships will see to it that ten or twelve members of their own crews receive practise as Marine Transfer winchmen.

However, there is another lesson in these experiences, namely, to reduce the winches to the limit of simplicity, to make them extra strong and fool-proof even if their capacity should be somewhat reduced. Also to simplify the control so that it may be acquired in an hour's practise if possible. This lesson has been taken advantage of in designing the winches now under construction for the new collier Neptune.

### MAXIMUM COALING EFFICIENCY.

The author believes that the maximum efficiency in coaling will be attained by employing clamshell buckets delivering coal in bulk directly into bunkers when possible and when impossible to hoppers on the deck of the ship to be coaled. Such hoppers to be arranged so that trucks holding about one ton of coal can be pushed beneath the hopper and filled therefrom by the movement of a valve or gate, the coal then to be trucked to various parts of the deck where it can be dumped through coal chutes to the bunkers. Such a method would reduce the number of men involved to a minimum. It would save the cost of coal bags or baskets. It would save the fatigue of the sailors from shovelling coal, carrying baskets or dragging bags of coal on the deck. Plate 43 illustrates such a form of hopper. This is shown as being constructed in one of the large hatches on one of the decks and delivering its coal to trucks on the deck below. Such hoppers should be a part of the battleship's construction or equipment. An ingenious engineer might design a combined skylight and coal hopper which would not add to the weight of the ship. The trucks should either be dismantled to be packed in a small space or carried on the colliers.

### COALING WITH BAGS.

The author believes that coaling with bags will gradually give way to coaling in bulk and a great saving in the cost of bags will then accrue to the Navy. In coaling with bags it takes two men to hold the bag while a third man shovels coal into it. Bags soon wear out and, even when they are stowed away, are liable to mildew and rot. After the coaling is finished the bags are usually washed, dried and stowed away.

### BAG-FILLING HOPPERS.

In case it becomes desirable for any reason to coal with bags it is suggested that these colliers be provided with hoppers to be filled with a clamshell bucket, these hoppers to be constructed so that the coal may spout directly into bags. Thus one man could fill bags from the hopper as rapidly as seven can working in the hold shovelling by hand. This is the result attained by bag-filling hopper barges in use by the British Admiralty.

### MARINE TRANSFER WINCHES.

The introduction on board ship of machinery to operate a clamshell bucket was new before these ships were built and no ship's winch had ever been constructed for this purpose. Deck space is valuable and limited. It is also important to save weight of machinery. The winches shown in Plates 37 and 44, occupy a space of only 7 feet 8 inches by 5 feet 10½ inches. They weigh 9,400 pounds each. These winches have only 8¼-inch by 10-inch double cylinders, yet they have proven to be capable of handling one gross ton of coal with perfect ease and ample factor of safety. In shore towers operating clamshell buckets, two 10-inch by 12-inch cylinders are the smallest used for this size of bucket. Drums driven by wood-and-iron friction clutches are employed on shore towers very extensively and with a fair degree of success, but on shore towers there is ample space for winches having friction clutches of large diameter. Even 40-inch, 50-inch and 60-inch frictions are employed in some instances. Large friction surfaces are necessary (when wood and iron are used) to dissipate the heat developed by the friction drums repeatedly thrown in and out of engagement. The deck space available on these five colliers limits the diameter of the friction clutches to something like 24 inches, and wood-and-iron or leather-and-iron frictions become impracticable. The winches referred to and illustrated herein have flat metallic frictions provided with air-cooling passages and even these get extremely hot in the course of a run of a single hour, but never hot enough to affect the operation.

In a competitive test at the New York Navy Yard between winches having metallic friction clutches and others of wood and iron of same diameter the latter were rendered unfit for service after three hours' run. There was ¼-inch of charcoal on the woods. Throughout all of these tests the new winches showed no signs of trouble. They are enormously strong and will stand a great deal of abuse. The friction surfaces are polished and flat and will slip before any dangerous strain comes upon the gear. It is impossible to hoist the load suddenly by throwing the friction into contact. It will slip somewhat before picking up the load. If the friction is thrown in and the steam then turned on, the load will be properly accelerated and the results are better.

There are three important points involved in the design and construction of these winches.

1. The employment of flat metallic slipping frictions with air-cooling passages.

2. The employment of a lever control which makes the operation comparatively easy.

3. The position of the operator is such that he can see the bucket in all parts of the hold as well as in every position it might take above the hatch.

The metallic slip frictions on all of these colliers involve the use of an extra hard steel plate attached to the gear and the employment of friction blocks made of a special composition. These materials are wonderfully durable and none has as yet shown any signs of wear.

## ROPES.

Wire seems to be the only material of which to make the ropes properly. Manila rope would fill the drums too full. This would require larger drums and more space and weight than is permissible on board ship. Furthermore, to keep the two bucket ropes free a non-spinning rope is found to be essential. Non-spinning ropes from the nature of their construction are not as durable as the ordinary wire rope but it is believed that the problem of durability will yet be solved and wire ropes will be produced that will not wear out too rapidly. Even at the present rate of wear the cost of wire rope per ton of coal handled is believed to be very much less than that of the manila cordage made necessary in coaling with bags employing the battleship's winches. It is a matter of common comment that the manila coaling whips required on a single coaling of a battleship from lighters are rendered unfit for further service by the abuse which they get in coaling, using the ordinary form of winch heads.

### TIME REQUIRED TO SET UP THE MARINE TRANSFER.

On the collier Vestal it has been found that in a comparatively smooth sea the entire Marine Transfer can be set up before entering the harbor and before the hatches are opened. After going alongside it is only a few moments' work to drop the booms in place, take up the slack of the ropes and begin discharging coal. This is possible because four independent hoisting drums are employed. It is also found that after the men are made familiar with the gear that the Marine Transfer can be set up nearly as quickly as the "Yard and Stay."

### U. S. COLLIER NEPTUNE.

The U. S. Collier Neptune is now building at the Maryland Steel Company's yard. This Company equipped the Mars, Vulcan and Hector with Marine Transfers. They devoted several months to finding the simplest form of coal-handling gear for the new collier Neptune. Several plans were completely drawn up and the cost and weight of the supporting gear carefully estimated.

The Marine Transfer was adopted only after all the usual methods of handling coal afloat or ashore had been given careful consideration. They are constructing a novel form of mast and boom to carry the Marine Transfer. The mast and boom structure is practically a series of structural steel tower-like masts tied together by a stiff member at their tops. Each individual mast or tower carries four booms. These booms are to be outstretched when the Marine Transfers are operated. The double blocks are suspended from the member connecting the tops of the masts and located directly over the center of the hatches.

The winches for this installation are of new design and will have double 9-inch by 10-inch cylinders. They are reversible and the control is so simplified that one man will operate two winches. It is hoped they will prove "fool-proof."

There are two pump handle levers and one foot brake for use in operating the clamshell bucket. In this way the twelve hatches on the collier Neptune will be operated by twelve men instead of twenty-four as would be the case had the Vestal equipment been adopted. Corresponding winches have been produced that ordinary Italian stevedores have become accomplished in handling in an hour's time. Metallic slipping friction drums with air-cooling passages will be provided. The winches are stronger than those on the Vestal, equally fast, and should easily deliver 100 tons of coal per hour as required by the Navy Department.

## EARLY PAPERS ON COALING WARSHIPS.

A most exhaustive paper, entitled "The Coaling of Warships," was read before the American Society of Naval Engineers by Commander J. R. Edwards, U. S. N., and published in their Journal of February, 1901.

Another paper by Commander Niblack, entitled "Colliers and Coal Stations," was published in the Proceedings of the United States Naval Institute in 1904, in which he gives the capacity of some of our coaling stations as follows:—

| | |
|---|---|
| At Frenchman's Bay | 10,000 tons. |
| Navy Yard, Portsmouth, N. H | 10,000 tons. |
| U. S. Navy Yard, Boston, Mass | 12,000 tons. |
| New London, Conn | 10,000 tons. |
| U. S. Navy Yard, New York | 9,000 tons. |
| U. S. Navy Yard, League Island | 3,000 to 5,000 tons. |
| U. S. Navy Yard, Washington, D. C | 3,000 tons. |
| Port Royal, S. C | 5,000 tons. |
| Sitka, Alaska | 5,000 tons. |
| Naval Station, Tutuila, Samoa | 5,000 tons. |

In contrast to these eleven modern coaling stations our new colliers carry 12,500 tons of coal each, more coal than at any of the above coaling stations. Every one of these colliers is equipped to discharge coal at a rate exceeding 1,000 tons of coal per hour. Such colliers cost about a million dollars each. They are perfectly equipped floating coaling stations. They can go anywhere.

# APPENDIX.

## Official Test U. S. Collier Vulcan, September 17, 1909, at Norfolk, Va.

| No. of load. | Min. | Sec. | Round trip. | No. of load. | Min. | Sec. | Round trip. | No. of load. | Min. | Sec. | Round trip. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 secs. | 29 | 10 | 30 | 20 secs. | 57 | 20 | 56 | 21 secs. |
| 2 | 0 | 23 | 23 secs. | 30 | 10 | 51 | 21 secs. | 58 | 21 | 19 | 23 secs. |
| 3 | 0 | 41 | 18 secs. | 31 | 11 | 20 | 29 secs. | 59 | 21 | 38 | 19 secs. |
| 4 | 1 | 0 | 19 secs. | 32 | 11 | 40 | 20 secs. | 60 | 22 | 1 | 23 secs. |
| 5 | 1 | 20 | 20 secs. | 33 | 12 | 0 | 20 secs. | 61 | 22 | 20 | 19 secs. |
| 6 | 1 | 40 | 20 secs. | 34 | 12 | 20 | 20 secs. | 62 | 22 | 50 | 30 secs. |
| 7 | 1 | 58 | 18 secs. | 35 | 13 | 12 | 52 secs. | 63 | 23 | 10 | 20 secs. |
| 8 | 2 | 20 | 22 secs. | 36 | 13 | 31 | 19 secs. | 64 | 23 | 29 | 19 secs. |
| 9 | 2 | 39 | 19 secs. | 37 | 13 | 53 | 22 secs. | 65 | 23 | 50 | 21 secs. |
| 10 | 3 | 58 | 79 secs. | 38 | 14 | 13 | 20 secs. | 66 | 24 | 8 | 18 secs. |
| 11 | 4 | 18 | 20 secs. | 39 | 14 | 33 | 20 secs. | 67 | 24 | 29 | 21 secs. |
| 12 | 4 | 38 | 20 secs. | 40 | 14 | 54 | 21 secs. | 68 | 24 | 49 | 20 secs. |
| 13 | 4 | 57 | 19 secs. | 41 | 15 | 19 | 25 secs. | 69 | 25 | 7 | 18 secs. |
| 14 | 5 | 17 | 20 secs. | 42 | 15 | 43 | 24 secs. | 70 | 25 | 27 | 20 secs. |
| 15 | 5 | 37 | 20 secs. | 43 | 16 | 5 | 22 secs. | 71 | 25 | 45 | 18 secs. |
| 16 | 5 | 56 | 19 secs. | 44 | 16 | 26 | 21 secs. | 72 | 26 | 3 | 18 secs. |
| 17 | 6 | 15 | 19 secs. | 45 | 16 | 45 | 19 secs. | 73 | 26 | 25 | 22 secs. |
| 18 | 6 | 38 | 23 secs. | 46 | 17 | 6 | 21 secs. | 74 | 26 | 43 | 18 secs. |
| 19 | 6 | 59 | 21 secs. | 47 | 17 | 25 | 19 secs. | 75 | 27 | 2 | 19 secs. |
| 20 | 7 | 27 | 28 secs. | 48 | 17 | 45 | 20 secs. | 76 | 27 | 23 | 21 secs. |
| 21 | 7 | 48 | 21 secs. | 49 | 18 | 5 | 20 secs. | 77 | 27 | 45 | 22 secs. |
| 22 | 8 | 7 | 19 secs. | 50 | 18 | 26 | 21 secs. | 78 | 28 | 12 | 27 secs. |
| 23 | 8 | 27 | 20 secs. | 51 | 18 | 47 | 21 secs. | 79 | 28 | 32 | 20 secs. |
| 24 | 8 | 47 | 20 secs. | 52 | 19 | 10 | 23 secs. | 80 | 28 | 50 | 18 secs. |
| 25 | 9 | 10 | 23 secs. | 53 | 19 | 32 | 22 secs. | 81 | 29 | 10 | 20 secs. |
| 26 | 9 | 30 | 20 secs. | 54 | 19 | 52 | 20 secs. | 82 | 29 | 30 | 20 secs. |
| 27 | 9 | 50 | 20 secs. | 55 | 20 | 15 | 23 secs. | 83 | 29 | 50 | 20 secs. |
| 28 | 10 | 10 | 20 secs. | 56 | 20 | 35 | 20 secs. | 84 | 30 | 12 | 22 secs. |

## Official Test U. S. Collier Vulcan, September 17, 1909, at Norfolk, Va.—Continued.

| No. of load. | Min. | Sec. | Round trip. | No. of load. | Min. | Sec. | Round trip. | No. of load. | Min. | Sec. | Round trip. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 85 | 30 | 32 | 20 secs. | 109 | 40 | 8 | 24 secs. | 133 | 50 | 14 | 29 secs. |
| 86 | 30 | 52 | 20 secs. | 110 | 40 | 27 | 19 secs. | 134 | 51 | 33 | 79 secs. |
| 87 | 31 | 14 | 22 secs. | 111 | 40 | 47 | 20 secs. | 135 | 51 | 54 | 21 secs. |
| 88 | 31 | 34 | 20 secs. | 112 | 41 | 6 | 19 secs. | 136 | 52 | 15 | 21 secs. |
| 89 | 31 | 53 | 19 secs. | 113 | 41 | 25 | 19 secs. | 137 | 52 | 35 | 20 secs. |
| 90 | 32 | 10 | 17 secs. | 114 | 41 | 47 | 22 secs. | 138 | 52 | 55 | 20 secs. |
| 91 | 32 | 35 | 25 secs. | 115 | 42 | 10 | 23 secs. | 139 | 53 | 16 | 21 secs. |
| 92 | 32 | 54 | 19 secs. | 116 | 42 | 36 | 26 secs. | 140 | 53 | 37 | 21 secs. |
| 93 | 33 | 23 | 29 secs. | 117 | 43 | 4 | 28 secs. | 141 | 54 | 0 | 23 secs. |
| 94 | 33 | 45 | 22 secs. | 118 | 43 | 27 | 23 secs. | 142 | 54 | 22 | 22 secs. |
| 95 | 34 | 22 | 27 secs. | 119 | 44 | 24 | 27 secs. | 143 | 54 | 45 | 23 secs. |
| 96 | 34 | 43 | 21 secs. | 120 | 44 | 44 | 20 secs. | 144 | 55 | 7 | 22 secs. |
| 97 | 36 | 1 | 18 secs. | 121 | 45 | 4 | 20 secs. | 145 | 55 | 33 | 26 secs. |
| 98 | 36 | 22 | 21 secs. | 122 | 45 | 25 | 21 secs. | 146 | 56 | 7 | 34 secs. |
| 99 | 36 | 42 | 20 secs. | 123 | 45 | 48 | 23 secs. | 147 | 56 | 31 | 24 secs. |
| 100 | 36 | 59 | 17 secs. | 124 | 46 | 9 | 21 secs. | 148 | 56 | 52 | 21 secs. |
| 101 | 37 | 26 | 27 secs. | 125 | 46 | 30 | 21 secs. | 149 | 57 | 22 | 30 secs. |
| 102 | 37 | 44 | 18 secs. | 126 | 46 | 53 | 23 secs. | 150 | 57 | 44 | 22 secs. |
| 103 | 38 | 3 | 19 secs. | 127 | 47 | 16 | 23 secs. | 151 | 58 | 13 | 29 secs. |
| 104 | 38 | 26 | 23 secs. | 128 | 47 | 44 | 28 secs. | 152 | 58 | 33 | 20 secs. |
| 105 | 38 | 45 | 19 secs. | 129 | 48 | 33 | 49 secs. | 153 | 59 | 3 | 30 secs. |
| 106 | 39 | 3 | 18 secs. | 130 | 48 | 56 | 23 secs. | 154 | 59 | 28 | 25 secs. |
| 107 | 39 | 24 | 21 secs. | 131 | 49 | 18 | 22 secs. | 155 | 59 | 51 | 23 secs. |
| 108 | 39 | 44 | 20 secs. | 132 | 49 | 45 | 27 secs. | ... | .. | .. | ..... |

It will be noted that 70 out of the 155 loads were each delivered in 20 seconds or less.

## ELECTIONS TO MEMBERSHIP.

*From Associate to Member* (1).

W. P. Stephens, Yacht Designer, now Editor "Lloyd's Register of American Yachts," Avenue A and 32d Street, Bayonne, N. J.

*For Members* (4).

Charles B. Calder, General Manager, Toledo Shipbuilding Co., Toledo, Ohio.

Howard C. Davis, Assistant to the Chief Engineer, Marine Department, Griscom Spencer Co., 80 West Street, New York, N. Y.

John F. McIntosh, Chief Engineer, Union Oil Co., Mills Building, San Francisco, Cal.

Daniel G. McAlpine, Marine Superintendent, Old Dominion Coal Co., Sydney, Nova Scotia.

*For Associate* (5).

A. Edward Bowers, Chief Draughtsman, Hull Department, Staten Island Shipbuilding Co., Port Richmond, S. I.

Carl A. Carlson, Civil Engineer, U. S. Navy, Bureau of Yards and Docks, Navy Department, Washington, D. C.

A. Clifton Leaveson, Chief Draughtsman, Engineering Department, Staten Island Shipbuilding Co., Port Richmond, S. I.

Joseph S. Shultz, Civil Engineer, U. S. Navy, Bureau of Yards and Docks, Navy Department, Washington, D. C.

Naoji Tomikawa, Chief Draughtsman, Mitsu Bishi Dockyard and Engine Works, Kobe, Japan.

*For Junior* (1).

Roy P. Mills, Draughtsman, Hull Division, Navy Yard, New York, N. Y.

THE CHAIRMAN:—You have heard the names, gentlemen. Is it your pleasure that the recommendation of the Council be approved and these gentlemen who have been named be elected Members and Associates.

It was moved, seconded and carried unanimously that the gentlemen named be elected Members and Associate Members of the Society.

The first paper on the program is "The Gyroscope for Marine Purposes," which will be read by its author, Mr. Sperry.

MR. ELMER A. SPERRY, *Member:*—Mr. Chairman and gentlemen, I will first read my paper and then have the stereopticon views. This subject of the application of the gyroscope to marine purposes has been a subject that has interested me for many years. Last year while abroad I made it a point to see every one who could be found conveniently who had written on the subject of the gyroscope or who had touched upon its application in any way; and I assure you I met a very interesting group of men, the master of which is our good friend Dr. Schlick, and although our rules would not allow me to publish his portrait, which was taken at the instance of Sir William H. White while Dr. Schlick was with him in London, still I have a slide in which we will see his genial face before we are through. I found quite a number of people in Germany who were interested in the gyroscope, but usually in a very theoretical way. Few seemed to have much idea of its practicable appreciation outside of Dr. Schlick, and possibly Brennan in England, and one or two others.

I might say one word on how Dr. Schlick happened to approach this subject. He had for a number of years noticed a peculiar action of side-wheel steamers. As a side-wheel steamer rolls, her prow swings round in the direction in which the roll takes place. He thought about this phenomenon a great deal and what utilization could be made of it, and it led to his work of installing his first gyroscope upon the sea bar, which we will see in the views. When he read his paper before the Institution of Naval Architects, more than one Englishman jumped up and said there was nothing peculiar in what the Doctor had seen, that the prow of a side wheel and every other ship swung round as her roll took place. The testimony was so strong against Dr. Schlick's observation that he could only get up and say:—"Well, I saw it;" and he did see it. The motion he observed was absolutely opposite to the motion referred to by his critics and known as yawing. When a ship yaws, it goes in an opposite direction, but when a side-wheeler has this gyroscopic motion it goes off in the same direction as the roll.

# THE GYROSCOPE FOR MARINE PURPOSES.

By Elmer A. Sperry, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

The uses of the gyroscope at sea fall properly under four general divisions:—First, in affording means for resisting and preventing rolling of vessels or even rolling and controlling their motions at will; second, its use as a marine compass; third, for holding automobile torpedoes to their course; fourth, for artificial horizons in connection with observations at sea. There are two other uses which may be noted, that of recording the motions of ships, and also the use of a small gyroscope in controlling the oscillation of large active gyroscopes for purposes of preventing rolling motions of the ship in their inception, and thus holding the ship against rolling. The first three only will be treated briefly in this paper.

Previous to the introduction of the gyroscope, there have been three methods of steadying ships which afforded resistance to roll. "The oldest steadying gear," as pointed out by Sir John I. Thornycroft, "was probably the sail, though not originally intended for that purpose." He goes on to say "that the extended use of steam is depriving passenger vessels of this ancient steadying gear and causing increased rolling. For comfort at sea, we require in our ships some device that will afford resistance to roll, the need being an increasing one."

Lord Kelvin has measured angles of roll in crossing the Atlantic of 40 degrees each side of the vertical, giving a total angle of motion in a single roll of 80 degrees.

The early work of Froude, his co-laborers and successors, in applying athwartship tanks for prevention of rolling is well known. These, together with rolling ballast and the great moving weight of Thornycroft himself, all fall under the head of moving the center of gravity of the ship in attempting to balance the wave effect and prevent rolling.

In the seventies bilge keels were introduced and their characteristics are quite well understood, being effective only in heaviest rolling. Quite large bilge keels were found to equal about three-fourths of the surface hull and keel action for all angles of roll. The comparison between bilge keels and one per cent. of water ballast in athwartship tanks is interesting. Very large keels were found to be only one-eighth as effective at 3 degrees

roll from the vertical, one-fourth as effective at 5 degrees roll, only equaling at 12 degrees roll, and being three times as effective at 18 degrees roll. They are also known to increase materially the resistance, skin friction and motive power required in all weathers. Sir John I. Thornycroft introduced a method of anticipating the rolling by the means of a controlling mechanism compounded of many active features involving a short and a long pendulum, a retarding device and a cataract all organized to co-act; these were operated on the floating link principle, a moving ballast being operated by heavy hydraulic machinery in the hold of the ship.

It is more than probable that the true engineering significance and the enormous power of the gyroscope were first discerned in this country; that is, observations concerning it were first made here. It happened in this wise. There was in the early history of our Navy a torpedo known as the Howell torpedo, which depended for its action upon the rapid rotation of a fly-wheel. The torpedo was a cigar-shaped craft and amidships there was a steel wheel some 16 inches in diameter that was rotated up to about 16,000 revolutions per minute. As a matter of fact, the speed of rotation was so great that the $\frac{1}{64}$-inch clearance left round the periphery was taken up by the centrifugal stresses acting upon the elasticity of the steel of the wheel, which was thus utilized as an automatic brake. This wheel was coupled to and served to drive the propellers when spun up.

We had in America at this early time the forerunner of the present steam turbine, viz., the Dow steam turbine, which was directly connected in such a way as to spin the massive wheel up to 16,000. Mr. Nixon, late of the U. S. Navy, had charge of some attempts at marksmanship with the Howell torpedo. He was anchored out in the bay, a certain distance from the target, and some difficulty was experienced in starting the steam turbine. But finally, after quite a lapse of time, the crew succeeded in getting the turbine going and gradually spun the wheel up. You understand it takes considerable time to store energy in a revolving mass and attain this high velocity. After the velocity had been reached and everything was ready, lo and behold!—the ship on which the machinery was located, anchored out in the bay, had turned, the tide having changed, and instead of the torpedo now being pointed at the target, it was found that the target was considerably to one side of the direction in which the torpedo now pointed. Mr. Nixon called upon some of the members of his crew to change the torpedo and point her over toward the target, but they found this difficult. They had no trouble in getting it up, but no amount of effort sufficed to budge it laterally; it would not change its direction. So the lieutenant called for more men. It simply had to come and finally it started slowly

and the men trod the deck. He saw they changed its relative position upon the boat considerably, so he stepped back and took a sight as to its alignment with the target and to his great surprise he found the target was still in the same quarter. In their efforts they had moved the ship around under the torpedo which contained the spinning wheel and which had refused to move. Now this was one of the first times that the real power of the gyroscope had manifested itself; it became noted in engineering circles.

As to some of the other uses of the gyroscope. The most extensive use to-day is probably the automatic steering gear in Whitehead torpedoes. This gear is simply used for the purpose of lateral guiding of the torpedo and holding same to a straight course. This little gyroscope has a secondary ring which may precess—it offers positive resistance to any effort to turn it from its course, and this resistance is used to operate valves and, through a secondary motor, the rudders. This use originated with Obrey, an Austrian naval officer (see Plate 45).

Our own member Mr. Leavitt, engineer of the E. W. Bliss Co., of New York, and inventor of the Bliss-Leavitt torpedo, has greatly increased the efficiency of the "gyro" gear of torpedoes, as he has greatly improved the torpedo itself. Figuring from the increased speed and radius of action, he has increased the power factor of the old Whitehead torpedo twenty times and without materially increasing the air pressure carried. He has accomplished this by a wonderfully bold piece of engineering; that is, by automatically burning a fuel directly in the pressure air current, thus greatly increasing its temperature. The reciprocating engine of the Whitehead is replaced by a pair of little Curtiss turbines. It should be remembered that every doubling of the absolute temperature doubles the volume, and whereas he starts out with a small amount of air, he reaches the turbine with an immense quantity of air, under the requisite pressure, enormously increasing the power generated, an exceptionally interesting piece of engineering!

Figures 2 and 3, Plate 46, show two types of the Leavitt directing gyroscope; this is small and he has increased its accuracy by unloading the base ring; instead of asking the base ring to do the work of moving a valve, he cuts the duty required down to about one-hundredth of that required in the Obrey gear and makes it give a simple directive factor to an extremely small pivoted pawl at the instant the pawl is otherwise perfectly idle. Plate 47 shows this vibrating pawl at E.

Dr. Schlick, a noted engineer of Hamburg, Germany, has done much in connection with the gyroscope. It is to Dr. Schlick's genius that we largely owe the vibrationless reciprocating marine engine. This engineer has gone further in the installation of large gyroscopes for steady-

ing ships than any other. His gyroscope is of the passive type. He is a practical engineer, and at first called to his assistance a number of other engineers and mathematicians and designed the first machine. The working drawings of one of these machines are of interest; they are presented as follows:—Plate 48 is a plan, Plate 49 is a forward elevation, and Fig. 8, Plate 50, a side elevation. Plate 51 shows the complete machine as it was installed on board the Silvanna.

In Germany, in 1909, Engineer Dr. Frahm had succeeded in overcoming one of the reasons for eliminating the water chambers from the old English men-of-war—that was the noise of the hundreds of tons of water rushing from side to side, which is said to have been intolerable—by using an inverted siphon. The trouble with this arrangement is that the central opening has to be of such a character as to cause the movement of the water to be synchronous with the boat's period; that is, if in addition to the simple gravitational factor of the water the kinetic energy of the rushing water is to be utilized; while the boat in still water has a fairly uniform period and the movement of the water in the arrangement can be made to conform to a given period, in rough seas, however, the boat is not periodic, varying a great deal. I have seen automatic diagrams of rolling where the period varied from seven seconds to seventeen seconds. Now when the flow of this great quantity of water gets out of synchronism it becomes a menace, and makes the boat roll more and behave worse. Some rolling diagrams are shown in Fig. 10, Plate 50.

The eminent engineer, Sir John I. Thornycroft of England, did much valuable work in attempts to overcome the last-named difficulty. He placed a great moving weight on a vertical axis which could move as a pendulum in the hold of the ship. An equipment of hydraulic apparatus was provided for swinging this weight from side to side (see Plate 52). By this means the center of gravity of the ship could be changed at will. The weight was about 5 per cent. of the total displacement of the ship, but it was governed by the controlling apparatus mentioned above, in such a way that he succeeded admirably in anticipating all the needs of the ship up to the capacity afforded by this moving weight. The weight had the power of tilting the ship just 2 degrees either side of the vertical when swung to its extreme lateral positions. In sea trials of this arrangement, Sir William White states that it reduced 18 degrees of roll to 9 degrees. To eliminate wind and weather conditions the boat was made to sweep through an entire great circle in heavy seas. This was the first attempt to steady a ship by a controlled reactionary force. The difficulties encountered with this, the water tanks and all other gravitational methods, are that

each pound of weight is enabled to do the work of only one pound and the weights and auxiliary machinery required have been thought to be prohibitive; and furthermore, the weight, when on one side or the other, constitutes a persistent unbalancing or listing force, whereas the gyroscope is enabled to deliver stresses pure and simple without disturbing the balance of the boat or introducing any such list whatever. The problem of preventing rolling of ships at sea has been attacked by a great many engineers.

Last year, while in Hamburg, I saw the latest arrangement of Engineer Frahm—some large naval vessels for the Russian Government now being built with his arrangement for steadying, involving enormous tanks amidships, which will contain from 350 to 400 tons of water through the rushing of which, back and forth, a part of the true periodic roll will be extinguished, but only a part and only when periodic. The eminent authority, Dr. Schlick, states with reference to this arrangement that it will become a positive menace and cause excessive rolling when the ship's oscillation falls out of period, which it invariably does in a storm. This, however, is interesting, as showing the great desire to prevent rolling of ships and especially war vessels.

The gyroscope, on the other hand, is not limited to any particular period of the boat; it simply responds to whatever motion the ship has, synchronous or non-synchronous. The question is often asked: Why is the gyroscope better than a moving weight in a ship for roll quenching? Barring the matter of list produced by the changes of center of gravity of the ship by the moving weight, the reason is perfectly apparent when you recall the magnitude of the stresses obtainable from a small machine. Every pound in the rotating mass of the gyroscope can easily be made to do the work of from 150 to 200 pounds, and directed in any desired line or plane, whereas, when we use water or any other form of moving weight, each pound represents a pound only, and can do the work of only a pound, and only in a vertical direction.

The gyroscope is probably the only device in the world by means of which stresses and also energy may be transferred "around a corner," so to speak. With the gyroscope it is possible to create and maintain a very powerful fulcrum in space effective for the heaviest kind of mechanical duty.

Now on board ship there is one factor that is stiff and is now available, and that is the fore-and-aft stability of the ship. In the gyroscope, for the first time, we have the means of rendering it possible to reach out and transfer this stability around a corner, so to speak, to the athwartships plane and thus hold the ship against rolling. We can do this with a surprisingly small mass, because, as I have said, every pound in that

mass can be made to do a very large amount of work, owing to the velocity that may, at low cost, be impressed upon it. One instance has been noted where the power required for operating the gyroscope would be about five per cent of that required for driving the bilge keels at normal speed of the boat, the keels requiring power in all weathers, the gyroscope only when needed.

A primary motion on the part of a body, for instance, the slow athwartship or rolling motion of a ship, exerts gyroscopic forces upon any vertical spinning shaft and in a fore-and-aft direction. These forces tend to dampen the rolling motion, but only feebly, and the fore-and-aft reaction, owing to the absence of motion, does not at all. It is a part of the general plan to so utilize this force as to make it create extremely large reactions athwartships or in the proper direction to be effective. This is accomplished by the ingenious yet simple expedient of mounting the aforesaid vertical shaft in a pivoted frame so that it can tilt and utilize the primary fore-and-aft reaction to cause the axis of the spinning mass to tilt fore and aft. This motion is of much higher velocity than the angular motion of the vessel which produces it. By means of this tilting motion an entirely new gyroscopic force is set up again at right angles as in the first instance, but now to the plane of tilt (fore-and-aft) which brings it back to the original athwartship plane just where needed; and, what is equally important, the reaction is in a direction exactly opposed to the roll of the ship which primarily called it into action, as well as this whole chain of phenomena which we have thus traced through a complete cycle of 180 degrees of angle and also through an enormous augmentation of righting moment and stabilizing power.

In Plate 53 we have a pendulum with a small gyroscope mounted upon it. This pendulum has freedom of oscillation upon its two gudgeons, all ship's roll being pendulic; this may be considered to be a ship with a small gyroscope upon it. The spinner weighs but little and it spins at a very low velocity compared with what a well-organized gyroscope will do.

## THE ACTIVE GYROSCOPE.

We note in Plate 54 that a cord is seen passing through the two gudgeons of the pendulum just above the tripods, and at a point midway between these gudgeons the cord passes around one of the little horizontal pulleys immediately below the gyroscope arranged in an elongated opening in the wooden top of the pendulum. These pulleys operate the little pinions in the lower middle portion of the fork of the gyroscope, one being geared directly to the base ring, shown horizontally in Plate 54, and the

other operating the precessional ring through an intermediate miter segment. This arrangement affords means whereby either of these rings may be tilted at will by the simple act of drawing the cord through the center of the gudgeons, and round either one or the other of the pulleys. No movement, manipulation or stress whatsoever applied to the cord, could in any way affect the oscillation of the pendulum for the reason just stated that the cord passes through the center or axis of this oscillation, and in line therewith.

It will be observed, in operating this model, that the gyroscope itself fails to respond to all the smaller angles. It responds freely to the large ones or wide angle oscillations, but either does not respond at all or moves very slightly with the smaller oscillations as stated. Not responding, it cannot, of course, control or extinguish these smaller oscillations. It being desired, especially in connection with improvement in conditions for gunnery on battleships and war vessels generally, that the gunner should operate if possible from a level gun platform, it therefore becomes desirable to act on these smaller oscillations of roll of the ship so as to completely extinguish them and hold the ship on a practically even beam. This especially as now all the larger war vessels are designed for broadside service and volley fire. The gunner therefore is compelled to keep an absolutely true and incessant aim upon the target. If the ship is rolling much or little this is a more difficult task. Again the recoil of the volley fire throws the boat over and sets up rolling, and it is the duty of the gyroscope to extinguish and prevent all rolling disturbances, from whatever source. As we have seen, the lesser angle rolling cannot be taken care of by the passive type of gyroscope. We must rely upon the active type. By this means the full angle operation of the gyroscope is secured where necessary, independently of the amount of motion or, in fact, any motion whatever on the part of the ship, and is therefore in readiness to deliver to the boat stresses which are equal and opposite to those received by the boat from any source and prevent them from causing the boat to roll.

It is interesting to note that when the boat is held free from motion, as by the delivery of stresses equal and opposite to balance the wave effort, no power is required to actuate the gyroscope other than to overcome inertia and friction, which is almost negligible. When the roll is being suppressed and the boat is moving then the boat is doing work upon the gyroscope, and it then becomes the province of the actuator to emplace the oscillations of the gyro properly with reference to those of the boat, and at such angular velocity as to best suit the conditions, structure and mountings.

The work of Sir John I. Thornycroft for preventing rolling, and his

devices, which are shown in Plate 52, involved changing the center of gravity of the vessel and thus introduced an additional disturbing and unstabling element which required additional treatment; his device involved a great moving weight running as high as 5 per cent. of the total displacement of the boat and a very large amount of hydraulic machinery for handling these weights and a considerable amount of motive power for operating them. But with the active type of gyroscope, we find that a small part of 1 per cent. of the displacement of the ship will perform a very substantial service, down to the point of practically fully extinguishing the rolling. By the use of this device there is entire absence of any shift of the center of gravity of the vessel, and its stability remains unchanged. The sizes, weights, speeds and location of a gyroscope for this purpose are among the points which have been canvassed in tests carried on at the Washington Navy Yard during the present year.

Plates 55 and 56 show front and rear views, respectively, of a working model of a 26,000-ton battleship of the super-dreadnought class, with five feet metacentric height and eighteen seconds period of roll, capable of rolling through a total arc of 60 degrees; means are provided for autographically recording all motions, both of the ship's model and the gyroscope, upon same. The gyroscope was operated both passively and actively; means were also provided for emplacing the discharge of the active gyroscope variously with regard to the ship's oscillation so that the effect of different combinations might be studied. Many other auxiliaries were provided, one of which permitted the actual velocities of the gyro wheel to be counted while in operation. This was accomplished by the stroboscopic apparatus of Capt. D. W. Taylor, similar to that used by him in his investigations of propellers under service conditions; in fact, both the ingenuity and reliability of performance of the model ship and the auxiliaries are directly due to Captain Taylor and his assistants at the Washington Navy Yard. By means of this very complete equipment studies and records have been made and charts of performance prepared and other valuable data accumulated, much of which is new, as many of the observations, we believe, were never before undertaken. The investigations with the active type of gyroscope are in a new line of research; the results obtained are important in point of much more perfect control of the ship's roll than heretofore possible.

Captain Taylor has prepared a very full report upon this work forming a part of which is a forty-page appendix in which he treats the question in a most masterly manner under some sixteen heads. In this most unique and valuable work, Captain Taylor has given an original mathematical

treatise on practically all the phases and bearings of this question, including an original investigation of the underlying phenomena of the gyroscope itself. It is of the greatest value to this important art that its problems should have come under the observation and been reviewed by so able a mathematician, experienced in all branches of experimental research, and fitted by long training to judge of the practical bearings of the results extending, as does this experience, to the very largest undertakings and structures in marine work. To give some idea of the great amount of work involved and also of the abstruse character of this work, I take the liberty of here reproducing (Plate 57) an isolated page of Captain Taylor's forty-page treatise above referred to. It is to be hoped that the author himself may be prevailed upon to give the Society a paper including this valuable treatise.

The practical effect in operation of the active type of gyroscope is to secure a large reduction of weight over and above that possible with the passive type. One of the reasons for this becomes apparent from the action of the pendulum which we have canvassed. With the smaller angles of roll, the gyroscope would have to be large enough so that its small angles of response would develop the required energy for extinguishing or still further reducing the roll, complete extinguishment being impossible; whereas with the active type the full 180 degrees oscillation of the gyroscope is always available, where required, for the extinguishment of large or even the smallest angles of roll as necessary. Thus an extremely small machine, taking advantage of the larger angles, between twenty and thirty times as large, is sufficient to accomplish this purpose.

Plate 58 illustrates three curves, one at the top giving the number of oscillations of the ship's model before it was brought to rest by the natural friction, having been originally tilted to 25 degrees to one side of the center. The shorter or central curve illustrates the number of oscillations of the model with the gyroscope acting passively or on Dr. Schlick's plan, the several rolls of smaller magnitude at the end being omitted where the passive type of gyroscope failed to respond; and a still shorter curve at the bottom shows the number of oscillations of the ship in being brought to rest, absolute freedom from motion being possible by the same gyroscope when operated actively. These are among the interesting results reached in the investigations referred to above.

When the motive power of vessels changed from an upsetting force to one almost exclusively of forward thrust, the design of ships underwent quite radical changes in connection with lines affecting the stability, decreasing this factor and favoring decreased resistance, aiding the attainment of higher speeds. Now that stability may be imparted to a structure of

naturally small righting movement, and, as is well known, even to structures in unstable equilibrium, it is possible that we are on the eve of even more radical changes in design. Ships may now be designed that are practically free from those ballistic qualities which favor rolling structures to which unequal sea pressures easily impart motion need no longer be employed, as a comparatively small gyroscope which can easily be present in duplicate, may very readily hold them practically free from rolling motions in such a way that ordinary seas will have little or no effect upon them, while an exceptional wave will have only a temporary effect. It has been suggested in connection with such vessels that they need not pitch if of sufficient length; be this latter fact as it may, it is apparent that a point has now been reached and a situation created with reference to the resisting and prevention of rolling and motion of ships at sea that, to say the least, is interesting in many quarters. I heartily commend this subject to those who are interested in providing safety and comfort to passengers at sea, and as also preventing deterioration of certain classes of freight; for instance, live stock is known to suffer heavy depreciation in stormy weather. This is entirely outside naval uses especially as related to gunnery, trimming ships to secure level gun platform, suppression of recoil from broadside firing, and other uses.

It is evident from what we know that the early workers were hampered by too close adherence to the earlier treatment of statical stability, and the direct effect of wave slope together with some other elementary factors, rather than the more practical considerations of the effect of movements of the ship, stresses involved, etc.

In 1904 Dr. Schlick presented a paper before the Institute of Naval Architects. Accompanying this paper in the form of an appendix is a mathematical treatise of the theory of the gyroscope and its application to steadying ships. There seems, however, to be little in this treatise which we find useful in the practical application of the gyroscope, especially the active type of gyroscope, to ships. The eminent authority, Captain Taylor, in his report on this subject states of this treatise that it is a very elaborate mathematical theory but that it largely ignores practical considerations.

The problem is a comparatively simple one, namely, of holding the ship against rolling by neutralizing with the gyroscope each disturbing influence as it reaches the ship while availing ourselves of all the aid possible through the design of the hull and disposition of the masses. With this end in view we do not yet know the best relation between these two factors. With the last adjusted to best fit the new conditions it is

believed that the gyro-steadying plant of the active type will be well within practical limits of space, weight and cost. Especially is this true when compared with the practical results of its operation. A great many ships as they now stand could with profit utilize the gyro-steadying gear of this class, which is at present available, and some important installations are now being contemplated. In this connection it is interesting to note that the weight of an active gyroscope for each degree of roll-quenching power on a modern battleship would be about one-tenth that of the submerged armor displaced, and cost much less, this being outside of the very important consideration of having the entire ship under control either automatically to extinguish roll or at the will of the commander with its many evident advantages.

Referring to the use of the gyroscope as a compass, it is interesting to note that the possibility was first brought out in 1852 by Foucoult, who, after many attempts, succeeded finally in making up an apparatus so delicate and beautifully constructed as to demonstrate the working of the instrument in the short period of duration of spins of a small disc, the observations being taken through a telescope, the directive factor being only a fraction of that of the magnetic needle. With this difference, however, that magnetism or the location and variations in the positions of the magnetic meridian have nothing whatever to do with its directive feature, and, in fact, it points to exact geographical north, not to magnetic north.

About this time Foucoult took this apparatus to England and there aroused the greatest enthusiasm in scientific circles by exhibiting it in operation to the Royal Society. Hopkins in America, associated with the "Scientific American," in 1878 made a small electrically driven gyroscope by means of which better and more persistent results were obtained. More recently, attempts have been made by a German firm to use mercury floats for sustaining the rotating wheel constituting a gyrostat which, in this instance, runs at the enormous speed of between 22,000 and 23,000 revolutions per minute, which has been considered by many to be impracticable. Those familiar with the use of mercury in its mechanical and also electrical applications usually find it very unsatisfactory. At best it is a volatile liquid, subject to many changes with differences in temperature, and, which is worse, is also subject to the phenomenon known as "sickening" which effects the surface and the mercury, and for some distance under the surface, altering its mechanical behavior and also its viscosity. The best engineering practice has for some years avoided mercury, drawing away from its use in every possible way, and especially where electrical connections were involved, and substituting, in its stead, simple mechanical methods which are free from these serious objections. Working in this line I have found simple detail

by means of which the whole gyroscope proposition is reduced to a strictly mechanical basis easily within the comprehension of all and containing no unknown quantities and correspondingly easily dealt with. In the cases where the gyroscope is employed as a battle compass, the apparatus is placed below decks, and small instruments about the size of an ordinary compass are distributed in different positions on the ship, giving the exact indications of the gyroscopic compass itself.

My work has extended to the point where action of such instruments can be controlled from the gyroscopic compass and distributed as desired, the indications being accurate to a very small fraction of a single degree. Many observations have been made indicating that they are accurate to thirty-six hundredths of an entire circle. Plate 59 shows a view of the battle compass as it is mounted on an artificial ship which gives all changes of heading, as well as automatic continuous roll and pitch to which the compass is continually subjected. Both roll and pitch may be varied at will as to angle and period.

Plate 60 shows one of the receiving instruments for the binnacle or other position. It is found that this receiving instrument requires no cardian mounting and is equally accurate in any position, vertical or horizontal. Indications are held with the accuracy described following the master instrument instantly, and are very much more "dead beat" than an air compass for marine purposes, though they are not submerged nor is any liquid used in connection with them. Among the points never before realized is the automatic correction of the northerly or southerly component of vessels' speed at sea, this correction being made between the gyroscopic compass and its transmitting member, in such a manner that the indications received by the navigator and elsewhere about the ship are thus absolute and maintain true geographical north.

A settling curve taken from my gyroscopic compass while in the operation of being started in the east and west position and brought up to about 4,000 revolutions per minute only shows the instrument to reach true north in 34 minutes; at normal speed the directive force is about 6,600 times that of the compass needle.

It is felt that the navigator has now at hand a most desirable aid and one that greatly simplifies his work.

It will be understood that this type of compass is not affected in the slightest degree by the steel of the ship, or cargo, nor any magnetic disturbances in either; neither should shifting cargo, turning turrets, gun-fire, nor the striking of a ship by a shot disturb its accuracy or reliability, nor is it affected in the slightest by those disturbances technically known as deviation or variation.

## DISCUSSION.

After the reading of his paper Mr. Sperry gave an exhibition of stereopticon views illustrative of the paper, after which, by means of a model in the shape of two tripods, with a pendulum beneath a small gyroscope, the paper was further explained by the author.

A MEMBER:—In operation, is the gyroscope confined vertically?

MR. SPERRY:—Oh no. It is pendulus and holds the plane of the axis of the earth with great accuracy.

I will now show you the model. (Illustrates by the use of the model.)

The conclusion of the paper and stereopticon views was received with great applause.

THE CHAIRMAN:—I certainly think, gentlemen, this paper deserves a hearty vote of thanks, and on behalf of the Society I tender the same to Mr. Sperry, and we stand adjourned until 2 o'clock this afternoon.

### AFTERNOON SESSION.

The Chairman called the meeting to order at 2.15.

THE CHAIRMAN:—I think, gentlemen, that we have rarely heard a more interesting paper than that of Mr. Sperry on the gyroscope and in your behalf I wish to renew our thanks to Mr. Sperry for his excellent illustrations.

The next paper is now before you, "Comparative Results in Steam and Coal Consumption with Turbines, Reciprocating Engines and a Combination of the Two on the Steam Yacht Vanadis," by Mr. Clinton H. Crane, Member.

# COMPARATIVE RESULTS IN STEAM AND COAL CONSUMPTION WITH TURBINES, RECIPROCATING ENGINES AND A COMBINATION OF THE TWO ON THE STEAM YACHT VANADIS.

By Clinton H. Crane, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

The steam yacht Vanadis, whose particulars are—

| | |
|---|---|
| Length over all | 279′ 0″ |
| Length, load water-line | 232′ 8″ |
| Beam | 32′ 6″ |
| Depth (Moulded) | 19′ 7½″ |
| Trial displacement | 1,450 tons |

was built on the Clyde at the yard of Messrs. A. & J. Inglis, from the designs of the writer, and delivered by them in the spring of 1908.

The propelling machinery consisted of the usual arrangement of Parsons turbines with a high pressure center and two low pressures driving the wing screws.

The guaranteed speed of the vessel was 15½ knots maximum, with a cruising speed of 13 knots, which was to be obtained on a guaranteed consumption of 26 tons of coal per 24 hours.

At the time the vessel was designed several turbine yachts had been constructed, no one of which had shown economy in coal consumption, so that very special stress was laid on this question of economy at cruising speed. As a consequence the turbines were designed primarily with this end in view.

Particulars of blading as follows:—

## S. Y. Vanadis.—Details of Turbine Blading.

| Turbine. | Drum diameter. | Number of rows. | Height of blade. | Blade section. | Pitch in inches. | Tip clearance. |
|---|---|---|---|---|---|---|
| One high pressure..... | 33″ | 18 | $\frac{5}{8}$″ | 120B | $\frac{7}{8}$″ | .03″ |
| | | 18 | $\frac{7}{8}$″ | 120B | $\frac{15}{16}$″ | .03″ |
| | | 18 | $1\frac{1}{4}$″ | 120B | 1″ | .035″ |
| | | 18 | $1\frac{3}{4}$″ | 130B | $1\frac{1}{4}$″ | .035″ |
| 30 rows of contact dummies, $\frac{1}{8}$″ section, $\frac{3}{8}$″ pitch. | | Dummy drum diameter 32″. | | | Dummy clearance .015″. | |
| Two low pressures..... | 44″ | 9 | $\frac{5}{8}$″ | 120B | $\frac{7}{8}$″ | .035″ |
| | | 9 | $\frac{7}{8}$″ | 120B | $\frac{15}{16}$″ | .035″ |
| | | 9 | $1\frac{1}{4}$″ | 120B | 1″ | .04″ |
| | | 9 | $1\frac{3}{4}$″ | 130B | $1\frac{1}{4}$″ | .05″ |
| | | 8 | $2\frac{1}{2}$″ | 130B | $1\frac{5}{16}$″ | .055″ |
| | | 8 | $3\frac{1}{2}$″ | 130B | $1\frac{3}{8}$″ | .06″ |
| | | 8 | 5″ | 130B | $1\frac{1}{2}$″ | .06″ |
| | | 8 | 5″ | 130B | $1\frac{5}{8}$″ | .06″S.W. |
| 22 rows of contact dummies, $\frac{1}{8}$″ section, $\frac{3}{8}$″ pitch. | | Dummy drum diameter $40\frac{5}{8}$″. | | | Dummy clearance .02″. | |
| Two astern..... | 32″ | 10 | $\frac{7}{16}$″ | 120B | $1\frac{1}{8}$″ | .04″ |
| | | 10 | $\frac{7}{8}$″ | 120B | $1\frac{1}{8}$″ | .05″ |
| | | 10 | $1\frac{3}{4}$″ | 130B | $1\frac{3}{8}$″ | .06″ |
| | | 10 | $1\frac{3}{4}$″ | 132B | $1\frac{1}{2}$″ | .06″ W. |
| 6 rows radial dummies, $\frac{1}{8}$″ section, $\frac{1}{2}$″ pitch. | | Dummy drum diameter $30\frac{3}{8}$″. Dummy clearance .02″ per side. | | | | |

The owner reported that the vessel was consuming very much more coal than the guaranteed amount, in fact, so much more that the steaming radius was most inconveniently short, the bunker capacity of 300 tons having been based on the coal consumption guaranteed with a safe margin for bad coal, foul bottom, etc.

At the writer's request an exhaustive series of tests was run in the autumn of 1908, after the turbines, propellers, condensing plant, etc., had been thoroughly overhauled to the approval of the New York representative of the Parsons Marine Turbine Co. During these tests Mr. H. B. Anderson and three assistants were present on behalf of the Company, the writer and staff from his office on behalf of the owner.

The method adopted for coal consumption test was to bag and weigh coal as it was needed.

Canvas bags with a capacity of about 200 pounds were used. These were filled in the bunkers and weighed by spring balance in the engine-room.

The usual precautions of calibrating balance, recording condition of fires at beginning and end of test, measuring water glasses and bringing boiler pressure to the same point were of course taken.

After the first eight hours two fires were cleaned each watch and the ashes pumped overboard through the ash ejector. All the usual auxiliary machinery was in use, ice machine being run about ten hours, sanitary pumps, dynamos, etc.

I append a tally sheet of two of these tests which shows how the weights of the bags varied. At the same time we made water measurements to help us determine whether the failure in economy was due to faults in the boilers or the machinery.

A water meter was installed but the results seemed so unreasonable that a check method was used by pumping all the condensed water by means of one of the feed-pumps which was controlled by a float in the hot well through a hose, and the output measured in barrels, the other feed-pump meantime feeding the boilers from the reserve tanks.

The Vanadis propellers had been partially standardized on the Clyde and several runs had been made in Glen Cove to determine the required number of revolutions to 13 knots. In the following spring, however, a complete standardization test was run at Provincetown, the various records of which are appended.

It will be noticed that the best test showed a consumption of 33 tons or 27 per cent. more than the guarantee. In view of this unfortunate condition it was possible to do one of three things:—

1. Lengthen the vessel to increase bunker capacity.

2. Remove turbines altogether and replace by twin reciprocating engines.

3. Remove the center high-pressure turbine and replace by a reciprocating engine, exhausting into the two low-pressure.

No. 3 was decided on. The contract for this alteration was let to the Staten Island Shipbuilding Company, and completed in January, 1910. In May following the vessel was run without propellers on the turbine shafts, being driven by the center propeller only, over the Glen Cove course, and subsequently a 4-hour water consumption test was run at the revolutions required for 13 knots. The vessel was then re-drydocked and the turbine propellers fitted to the wing shafts, and in July of the same year the complete standardization coal and water tests were run in the new condition.

In these latter two tests the water was measured in large sized measuring tanks in the engine-room, horse-power readings were taken, and the horse-power curves are shown in the appendix. I also show the speed revolution curves in the various conditions, and the slip curves of the three propellers.

There were present at these tests, in addition to the writer and members of his staff, Mr. George Cormack, Secretary, New York Yacht Club, and Mr. Ralph B. Strassburger to whom the writer is indebted for bridge observations, also Mr. George H. Bates and staff from the Staten Island Shipbuilding Company to whom he is indebted for assistance in the engine-room.

I wish to call attention to one matter of interest in these slip curves, that even at a considerable negative slip the wing propellers are still developing some thrust, as shown by the fact that the vessel is obtaining more speed per revolution with the turbine propellers working than without them.

I should also like to call attention to the indicator cards taken with the engine exhausting into the turbines and when exhausting into the condenser, and particularly wish to direct attention to the compression line of the low-pressure cylinder when exhausting into the turbines.

The summary of the coal and water consumption results of the three types of machinery is appended below. In measuring the water the steering engine steam is included, as it was always exhausting into the condenser. In estimating the amount of water used by the auxiliaries I have used a series of tests made at anchor of these auxiliaries. Apparently in the 13-knot condition with the combination, the propelling machinery is using about $14\frac{1}{2}$ pounds per indicated horse-power, with the reciprocating engine alone about 17 pounds, and with the turbines about $20\frac{1}{2}$ pounds. I say "about" because the indicators do not strike me as giving an absolutely truthful account of the amount of power—notice the irregularity in the way the spots run on the indicated horse-power revolution curve.

MACHINERY.

*Boilers:*—Two, single-ended Scotch, 16′0″ diameter, 11′9″ long. Four furnaces, 42″ diameter, each boiler 81 square feet grate.
Heating surface, 2,761 square feet each boiler.

*Engines* (Trials of October 5 and 6, 1908, to October, 1909):—Triple screw turbines. High-pressure turbine on center shaft and one low-pressure turbine on each side shaft.
Trials from January, 1910, on: One triple expansion reciprocating engine, on center shaft-cylinders, $18\frac{3}{4}'' \times 29'' \times 45''$, stroke 26″, and one low-pressure turbine on each side shaft.

## AUXILIARY MACHINERY.

*Blowers:*—Two 25″ diameter Sirocco blowers, and direct connected electric motors, delivering 16,000 cubic feet of air per minute against pressure of $2\frac{1}{2}$″ of water at fan; connected to double front of each boiler through steel casing.

*Dynamos:*—One 25 K. W.—Turbine-driven dynamo, running at 3,600 revolutions. One 15 K. W.—Direct connected dynamo, running at 400 revolutions.

*Ice machine:*—One J. & E. Halls No. 6.

*Steering engine.*

*Evaporator* of 7 tons capacity.

*Circulating pumps:*—Two centrifugal pumps, directly connected to independent engines.

*Air pumps:*—Two Blake single acting beam air pumps, 12″×22″×15″. One of these pumps was removed and an Edwards type driven by links from the horse-power crosshead was installed with the center engine.

*Feed pumps:*—Two Blake simplex, 12″×7″×16″.

*Donkey pumps:*—No. 1, Blake vertical duplex, 8″×6″×12″.
No. 2, Blake vertical duplex, 9″×6″×10″.
No. 3, Blake horizontal duplex, $5\frac{1}{4}$″×$3\frac{1}{2}$″×6″.

*Tank pumps:*—2 Blake horizontal duplex, $4\frac{1}{2}$″×$3\frac{3}{4}$″×4″.
1 Blake horizontal duplex, 3″×2″×3″.

*Oil pumps:*—2 small Weir oil pumps for lubricating turbine bearings.

## PROPELLER PARTICULARS.

3 turbines, diameter, 4′ 5″; pitch, 3′ 6″; area ratio, 47 per cent.
Center engine, diameter, 9′ 6″; pitch, 10′ 6″; area ratio, 40 per cent.
2 wing turbines, diameter, 4′; pitch, 3′ 3″; area ratio, 45 per cent.

## Summary Coal and Water Tests.

| Type machinery. | Date. | Mean draught. | Displacement, tons. | R.P.M. | Speed, knots. | Coal, tons per 24 hours. | Water, pounds per hour, propelling machinery only. | Water, pounds per hour, all purposes. | Water, pounds per hour, propelling machinery only, reduced to 13 knots. | Water, pounds per hour, all purposes, reduced to 13 knots. | Coal, tons, reduced to 13 knots. | I. H. P. for 13 knots. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 turbines | Oct. 5–6, 1908 | 12′9″ | 1,506 | 451.3 | 12.968 | 33.92 | ..... | ..... | ..... | ..... | 34.0 | ..... |
| 3 turbines | Oct. 14–15, 1908 | 12′2″ | 1,416 | 454.2 | 13.022 | 33.00 | 23,962 | 29,188 | 23,700 | 28,926 | 32.9 | ..... |
| Engine only | May 20, 1910 | 12′6″ | 1,467 | 152.4 | 12.968 | ..... | 19,000 | 23,000 | 19,152 | 23,152 | 25.0 | 1,135 |
| Combination engine and 2 turbines. | July 13, 1910 | 12′4″ | 1,442 | 141.2<br>452.0 | 13.3 | ..... | 18,400 | 22,960 | 17,700 | 22,260 | ..... | ..... |
| Engine and 2 turbines | July 14–15, 1910 | 12′2½″ | 1,422 | 140.9<br>452.5 | 13.3 | 23.47 | ..... | ..... | ..... | ..... | 22.7 | ..... |

## Summary—Comparison Glen Cove and Provincetown, Miles.

| Type machinery. | Date. | Course. | Mean draught. | Displacement, tons. | R. P. M. 13 knots. |
|---|---|---|---|---|---|
| 3 turbines—mean of 3..... | Oct. 5, 1908.... | Glen Cove.... | 12′9″ | 1,506 | 453.5 |
| 3 turbines—mean of 3..... | May 7, 1909.... | Provincetown. | 12′3½″ | 1,436 | 453.1 |
| Engine only..... | May 20, 1910... | Glen Cove.... | 12′6″ | 1,467 | 153.0 |
| Combination engine, turbines—mean of 2..... | July 12, 1910... | Glen Cove.... | 12′6½″ | 1,474 | 140.5<br>443.0 |
| Engine, turbines—mean of 2.... | July 13–14, 1910. | Provincetown. | 12′3½″ | 1,436 | 139.0<br>440.0 |

## SPEED REVOLUTIONS, PROVINCETOWN, MAY 7, 1909.

| Number of run. | Speed, knots. | Revolutions per minute. | | | Mean revolutions of three. | Remarks. |
|---|---|---|---|---|---|---|
| | | Center turbine. | Port turbine. | Starboard turbine. | | |
| 1 | 15.789 | 586.8 | 639.5 | 604.0 | 610.1 | By-pass open about 3½ turns. |
| 2 | 16.143 | 582.5 | 650.0 | 615.0 | 615.8 | |
| Mean of 1 and 2 | 15.966 | | | | 612.9 | |
| 3 | 16.071 | 570.0 | 671.1 | 636.9 | 626.0 | By-pass open 3½ turns. |
| 4 | 16.401 | | | | 640.0 | |
| Mean of 3 and 4 | 16.236 | | | | 633.0 | |
| 5 | 15.859 | 573.6 | 638.1 | 610.5 | 607.4 | Boat was lightened 1 inch before these runs were made. By-pass open 3½ turns. |
| 6 | 16.438 | 558.4 | 665.1 | 632.2 | 618.6 | |
| Mean of 5 and 6 | 16.148 | | | | 613.0 | |
| 7 | 16.107 | 576.4 | 658.1 | 623.3 | 619.3 | By-pass open 3½ turns. |
| 8 | 16.071 | 574.5 | 607.1 | 644.6 | 608.7 | |
| Mean of 7 and 8 | 16.089 | | | | 614.0 | |
| 9 | 15.158 | 560.0 | 603.0 | 556.0 | 573.0 | |
| 10 | 15.190 | 557.3 | 589.0 | 554.7 | 567.0 | |
| Mean of 9 and 10 | 15.174 | | | | 570.0 | |
| 11 | 15.037 | 538.0 | 573.0 | 538.0 | 549.6 | |
| 12 | 14.694 | 543.6 | 570.6 | 536.3 | 550.2 | |
| Mean of 11 and 12 | 14.865 | | | | 549.9 | |
| 13 | 14.643 | 513.3 | 535.2 | 500.0 | 516.2 | |
| 14 | 13.980 | 512.4 | 541.6 | 503.1 | 519.0 | |
| Mean of 13 and 14 | 14.307 | | | | 517.6 | |
| 15 | 13.873 | 473.8 | 491.1 | 455.3 | 473.4 | |
| 16 | 13.139 | 477.3 | 499.2 | 465.3 | 480.6 | |
| Mean of 15 and 16 | 13.506 | | | | 477.0 | |
| 17 | 12.973 | 436.7 | 446.7 | 406.8 | 430.1 | |
| 18 | 11.862 | 432.6 | 441.5 | 406.9 | 427.0 | |
| Mean of 17 and 18 | 12.417 | | | | 428.5 | |
| 19 | 11.921 | 386.6 | 385.6 | 356.8 | 376.3 | |
| 20 | 10.370 | 384.4 | 383.5 | 353.5 | 373.8 | |
| Mean of 19 and 20 | 11.145 | | | | 375.1 | |
| 21 | 9.904 | 309.0 | 303.2 | 282.7 | 298.3 | |
| 22 | 8.410 | 309.0 | 316.0 | 294.0 | 306.3 | |
| Mean of 21 and 22 | 9.157 | | | | 302.3 | |

## Progressive Measured Mile Trial, Friday, May 7, 1909, off Provincetown, Cape Cod.

| Number of run | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Time of day | 8–25 | 8–35 | 8–47 | 9–0 | 11–15 | 11–27 | 11–40 | 11–55 |
| Pressures: | | | | | | | | |
| Boilers | 164 | ..... | ..... | ..... | 162 | 160–162 | 162–164 | 156–158 |
| Main steam pipe | 146 | 150 | 144 | 145 | 142 | 144–137 | 145 | 144–139 |
| Horse-power turbine | 139 | 142.5 | 137 | 140 | 135.5 | 135–132 | 140 | 138–134 |
| By-pass | 3 turns. | 3½ turns. | 3½ turns. | 3½ turns. | 3½ turns. | 3½ turns. | 3½ turns. | 3½ turns. |
| Low pressure starboard | 28.50 | 29.5 to 35 | 35.5 | 35.5 | 32 | 35.5 | 33 | 30 |
| Low pressure port | 29.0 | 30 to 35 | 36.0 | 36.0 | 32 | 36.0 | 33.5 | 31 |
| Astern starboard | ..... | ..... | ..... | ..... | 23″ V. | 23″ V. | 23″ V. | ..... |
| Astern port | ..... | ..... | ..... | ..... | 23″ V. | 23″ V. | 28″ V. | ..... |
| Condenser starboard | 28″ | 28″ | 27.8″ | 27.6″ | 27.8″ | 27.8″ | 27.8″ | 28.3″ |
| Condenser port | 28.4″ | 28.5″ | 28.25″ | 28.2″ | 28.20″ | 28.4″ | 28.2″ | 28.7″ |
| Feed temperatures | 150° | 152° | 150° | ..... | 160° | 150° | 158° | 142° |
| Speed in knots | 15.789 | 16.143 | 16.071 | 16.401 | 15.859 | 16.438 | 16.107 | 16.071 |
| Mean speed | 15.966 | | 16.236 | | 16.148 | | 16.089 | |
| Revolutions per minute: | | | | | | | | |
| Center | 586.8 | 582.5 | 570 | ..... | 573.6 | 558.4 | 576.4 | 574.5 |
| Starboard | 604.0 | 615.0 | 636.9 | (?) | 610.5 | 632.2 | 623.3 | 607.1 |
| Port | 639.5 | 650.0 | 671.1 | ..... | 638.1 | 665.1 | 658.1 | 644.6 |
| Mean of three shafts | 610.0 | 615.8 | 626.0 | 640 | 607.4 | 618.6 | 619.3 | 608.7 |
| Apparent slip per cent | 25.0 | 24.0 | 25.75 | 25.75 | 24.40 | 23.15 | 24.50 | 23.50 |

Draught after putting one anchor and chain overboard at 9.30 A. M.

| | |
|---|---|
| Forward | 11′ 4″ |
| Aft | 13′ 3″ |
| Mean | 12′ 3½″ |

## Progressive Measured Mile Trial, Friday, May 7, 1909, off Provincetown, Cape Cod—Continued.

| Number of run | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| Time of day | 12–06 | 12–18 | 12–32 | 12–48 | 1–0 | 1–15 | 1–30 | 1–50 |
| Pressures: | | | | | | | | |
| Boilers | 162–165 | 170–171 | 158–160 | 155–157 | 148–151 | 161–163 | 160 | 160 |
| Main steam pipe | 150 | 160 | 149 | 147 | 140 | 153 | 153 | 153 |
| Horse-power turbine | 140 | 141 | 130 | 130 | 110 | 110 | 90 | 90 |
| By-pass | None. | None. | None. | None. | None. | None. | None. | None. |
| Low pressure starboard | 20 | 20 | 17 | 16.75 | 11 | 11.25 | 7.5 | 7.5 |
| Low pressure port | 20.5 | 21 | 18 | 18 | 12 | 12.5 | 7.5 | 7.5 |
| Astern starboard | ..... | ..... | 23″ V. | ..... | 24″ V. | 23″ V. | ..... | ..... |
| Astern port | ..... | ..... | ..... | 29″ V. | 29″ V. | 29″ V. | ..... | ..... |
| Condenser starboard | 28.5″ | 28.6″ | 28.6″ | 28.8″ | 29″ | 29″ | 29.1″ | 29″ |
| Condenser port | 28.9″ | 28.9″ | 28.9″ | 29.2″ | 29.2″ | 29.3″ | 29.25″ | 29.25″ |
| Feed temperatures | 158° | 154° | 150° | 140° | 144° | 150° | ..... | ..... |
| Speed in knots | 15.158 | 15.19 | 15.037 | 14.694 | 14.634 | 13.980 | 13.873 | 13.139 |
| Mean speed | 15.174 | | 14.865 | | 14.307 | | 13.506 | |
| Revolutions per minute: | | | | | | | | |
| Center | 560 | 557.3 | 538 | 543.6 | 513.3 | 512.4 | 473.8 | 477.3 |
| Starboard | 556 | 554.7 | 538 | 536.3 | 500 | 503.1 | 455.3 | 465.3 |
| Port | 603 | 589 | 573 | 570.6 | 535.2 | 541.6 | 491.1 | 499.2 |
| Mean of three shafts | 573.0 | 567.0 | 549.6 | 550.2 | 516.2 | 519.0 | 473.4 | 480.6 |
| Apparent slip per cent | 23.50 | 22.5 | 20.80 | 22.60 | 17.9 | 22.0 | 15.0 | 20.9 |

Micrometer measurements 12.40 P. M.

| | | | |
|---|---|---|---|
| Center | .025″ | Pressure | 130 lbs. |
| Port | .024″ | Pressure | 18 lbs. |
| Starboard | .026″ | Pressure | 17 lbs. |

## PROGRESSIVE MEASURED MILE TRIAL FRIDAY, MAY 7, 1909, OFF PROVINCETOWN, CAPE COD—Continued.

| Number of run | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|
| Time of day | 2–05 | 2–20 | 2–36 | 2–54 | 3–15 | 3–35 |
| Pressures: | | | | | | |
| Boilers | 155–158 | 165–167 | 148–152 | 155 | 155–153 | 156–159 |
| Main steam pipe | 150 | 160 | 145 | 150 | 148 | 152 |
| Horse-power turbine | 70 | 70 | 50 | 50 | 30 | 30 |
| By-pass | None. | None. | None. | None. | None. | None. |
| Low pressure starboard | 1.0 | 1.5 | 5″ V. | 14″ V. | 14″ V. | 14″ V. |
| Low pressure port | 2.75 | 3.0 | 4″ V. | 3″ V. | 11″ V. | 10″ V. |
| Astern starboard | 24″ V. | 24″ V. | 24″ V. | ..... | 24″ V. | ..... |
| Astern port | 29″ V. | 29″ V. | 29″ V. | ..... | 29″ V. | ..... |
| Condenser starboard | 28.3″ | 28.3″ | 27.8″ | 27.8″ | 28.5″ | 28.4″ |
| Condenser port | 29.1″ | 29.3″ | 28.9″ | 29″ | 28.5″ | 29″ |
| Feed temperatures | 148° | 148° | 160° | 155° | 172° | 175° |
| Speed in knots | 12.973 | 11.862 | 11.921 | 10.37 | 9.904 | 8.41 |
| Mean speed | 12.417 | | 11.145 | | 9.157 | |
| Revolutions per minute: | | | | | | |
| Center | 436.7 | 432.6 | 386.6 | 384.4 | 309 | 309 |
| Starboard | 406.8 | 406.9 | 356.8 | 353.5 | 282.7 | 294 |
| Port | 446.7 | 441.5 | 385.6 | 383.5 | 303.2 | 316 |
| Mean of three shafts | 430.1 | 427.0 | 376.3 | 373.8 | 298.3 | 306.3 |
| Apparent slip per cent | 12.5 | 19.5 | 8.25 | 20.5 | 4.0 | 20.75 |

| | |
|---|---|
| Barometer | 30.06″ |
| Sea | Smooth. |
| Wind | Moderate. |

## Twenty-four Hour Coal Consumption Test, October 5 and 6, 1908.

| Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 167 | 26 | 182 | 51 | 162 | 76 | 153 | 101 | 170 | 126 | 190 |
| 2 | 166 | 7 | 189 | 2 | 173 | 7 | 192 | 2 | 192 | 7 | 186 |
| 3 | 166 | 8 | 177 | 3 | 169 | 8 | 156 | 3 | 189 | 8 | 189 |
| 4 | 168 | 9 | 177 | 4 | 167 | 9 | 159 | 4 | 169 | 9 | 174 |
| 5 | 158 | 30 | 177 | 5 | 162 | 80 | 141 | 5 | 178 | 130 | 162 |
| 6 | 152 | 1 | 164 | 6 | 175 | 1 | 158 | 6 | 182 | 1 | 172 |
| 7 | 160 | 2 | 186 | 7 | 159 | 2 | 151 | 7 | 188 | 2 | 185 |
| 8 | 154 | 3 | 150 | 8 | 165 | 3 | 154 | 8 | 187 | 3 | 183 |
| 9 | 148 | 4 | 140 | 9 | 165 | 4 | 152 | 9 | 172 | 4 | 185 |
| 10 | 153 | 5 | 155 | 60 | 165 | 5 | 168 | 110 | 176 | 5 | 180 |
| 1 | 150 | 6 | 169 | 1 | 171 | 6 | 160 | 1 | 185 | 6 | 190 |
| 2 | 150 | 7 | 174 | 2 | 162 | 7 | 154 | 2 | 177 | 7 | 194 |
| 3 | 133 | 8 | 166 | 3 | 181 | 8 | 168 | 3 | 176 | 8 | 187 |
| 4 | 168 | 9 | 169 | 4 | 167 | 9 | 165 | 4 | 178 | 9 | 168 |
| 5 | 163 | 40 | 169 | 5 | 160 | 90 | 158 | 5 | 186 | 140 | 193 |
| 6 | 162 | 1 | 165 | 6 | 167 | 1 | 169 | 6 | 184 | 1 | 188 |
| 7 | 163 | 2 | 175 | 7 | 157 | 2 | 158 | 7 | 192 | 2 | 184 |
| 8 | 175 | 3 | 164 | 8 | 167 | 3 | 170 | 8 | 174 | 3 | 180 |
| 9 | 152 | 4 | 176 | 9 | 162 | 4 | 164 | 9 | 179 | 4 | 185 |
| 20 | 157 | 5 | 161 | 70 | 165 | 5 | 158 | 120 | 181 | 5 | 175 |
| 1 | 168 | 6 | 173 | 1 | 163 | 6 | 177 | 1 | 176 | 6 | 190 |
| 2 | 170 | 7 | 162 | 2 | 157 | 7 | 183 | 2 | 165 | 7 | 193 |
| 3 | 173 | 8 | 158 | 3 | 155 | 8 | 178 | 3 | 164 | 8 | 175 |
| 4 | 168 | 9 | 162 | 4 | 163 | 9 | 174 | 4 | 183 | 9 | 186 |
| 25 | 173 | 50 | 176 | 75 | 162 | 100 | 180 | 125 | 168 | 150 | 183 |
| Total.. | 4,017 | Total.. | 4,216 | Total.. | 4,121 | Total.. | 4,063 | Total.. | 4,491 | Total.. | 4,577 |

## Twenty-four Hour Coal Consumption Test, October 5 and 6, 1908—Continued.

| Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 180 | 176 | 193 | 201 | 194 | 226 | 186 | 251 | 154 | 276 | 168 |
| 2 | 192 | 7 | 185 | 2 | 202 | 7 | 185 | 2 | 179 | 7 | 165 |
| 3 | 187 | 8 | 185 | 3 | 212 | 8 | 183 | 3 | 159 | 8 | 173 |
| 4 | 207 | 9 | 175 | 4 | 199 | 9 | 170 | 4 | 156 | 9 | 175 |
| 5 | 175 | 180 | 176 | 5 | 207 | 230 | 188 | 5 | 157 | 280 | 154 |
| 6 | 205 | 1 | 146 | 6 | 217 | 1 | 181 | 6 | 163 | 1 | 160 |
| 7 | 192 | 2 | 180 | 7 | 200 | 2 | 176 | 7 | 171 | 2 | 172 |
| 8 | 205 | 3 | 164 | 8 | 203 | 3 | 168 | 8 | 167 | 3 | 170 |
| 9 | 192 | 4 | 180 | 9 | 185 | 4 | 165 | 9 | 168 | 4 | 182 |
| 160 | 194 | 5 | 180 | 210 | 180 | 5 | 168 | 260 | 169 | 5 | 171 |
| 1 | 193 | 6 | 145 | 1 | 190 | 6 | 154 | 1 | 173 | 6 | 175 |
| 2 | 193 | 7 | 165 | 2 | 176 | 7 | 169 | 2 | 164 | 7 | 157 |
| 3 | 192 | 8 | 178 | 3 | 195 | 8 | 153 | 3 | 163 | 8 | 163 |
| 4 | 181 | 9 | 185 | 4 | 180 | 9 | 170 | 4 | 170 | 9 | 173 |
| 5 | 160 | 190 | 180 | 5 | 198 | 240 | 164 | 5 | 165 | 290 | 167 |
| 6 | 180 | 1 | 170 | 6 | 200 | 1 | 142 | 6 | 162 | 1 | 160 |
| 7 | 138 | 2 | 175 | 7 | 214 | 2 | 131 | 7 | 165 | 2 | 162 |
| 8 | 188 | 3 | 185 | 8 | 205 | 3 | 149 | 8 | 170 | 3 | 173 |
| 9 | 190 | 4 | 168 | 9 | 208 | 4 | 146 | 9 | 167 | 4 | 166 |
| 170 | 185 | 5 | 180 | 220 | 182 | 5 | 164 | 270 | 168 | 5 | 174 |
| 1 | 187 | 6 | 195 | 1 | 177 | 6 | 160 | 1 | 184 | 6 | 170 |
| 2 | 192 | 7 | 195 | 2 | 183 | 7 | 162 | 2 | 177 | 7 | 166 |
| 3 | 179 | 8 | 193 | 3 | 183 | 8 | 150 | 3 | 172 | 8 | 170 |
| 4 | 180 | 9 | 193 | 4 | 183 | 9 | 161 | 4 | 165 | 9 | 156 |
| 175 | 176 | 200 | 194 | 225 | 185 | 250 | 164 | 275 | 173 | 300 | 182 |
| Total.. | 4,663 | Total.. | 4,563 | Total.. | 4,958 | Total.. | 4,109 | Total.. | 4,181 | Total.. | 4,204 |

## Twenty-four Hour Coal Consumption Test, October 5 and 6, 1908—Continued.

| Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 190 | 326 | 174 | 351 | 175 | 376 | 170 | 401 | 186 | 426 | 170 |
| 2 | 165 | 7 | 176 | 2 | 161 | 7 | 190 | 2 | 179 | 7 | 157 |
| 3 | 173 | 8 | 176 | 3 | 166 | 8 | 184 | 3 | 184 | 8 | 168 |
| 4 | 167 | 9 | 178 | 4 | 157 | 9 | 180 | 4 | 190 | 9 | 175 |
| 5 | 160 | 330 | 180 | 5 | 177 | 380 | 190 | 5 | 177 | 430 | 175 |
| 6 | 173 | 1 | 196 | 6 | 168 | 1 | 172 | 6 | 190 | 1 | 177 |
| 7 | 184 | 2 | 180 | 7 | 168 | 2 | 180 | 7 | 188 | 2 | 157 |
| 8 | 188 | 3 | 175 | 8 | 178 | 3 | 176 | 8 | 181 | 3 | 184 |
| 9 | 185 | 4 | 188 | 9 | 180 | 4 | 185 | 9 | 182 | 4 | 177 |
| 310 | 198 | 5 | 185 | 360 | 171 | 5 | 190 | 410 | 173 | 5 | 175 |
| 1 | 188 | 6 | 161 | 1 | 172 | 6 | 190 | 1 | 182 | 6 | 176 |
| 2 | 190 | 7 | 185 | 2 | 175 | 7 | 190 | 2 | 184 | 7 | 186 |
| 3 | 183 | 8 | 170 | 3 | 170 | 8 | 176 | 3 | 186 | 8 | 182 |
| 4 | 193 | 9 | 168 | 4 | 164 | 9 | 185 | 4 | 177 | 9 | 169 |
| 5 | 180 | 340 | 174 | 5 | 163 | 390 | 180 | 5 | 192 | 440 | 180 |
| 6 | 191 | 1 | 175 | 6 | 175 | 1 | 185 | 6 | 184 | 1 | 170 |
| 7 | 175 | 2 | 157 | 7 | 172 | 2 | 190 | 7 | 171 | 2 | 177 |
| 8 | 190 | 3 | 160 | 8 | 178 | 3 | 184 | 8 | 184 | 443 | 168 |
| 9 | 166 | 4 | 168 | 9 | 163 | 4 | 180 | 9 | 175 | Total.. | 3,123 |
| 320 | 178 | 5 | 183 | 370 | 168 | 5 | 187 | 420 | 189 | | |
| 1 | 188 | 6 | 168 | 1 | 186 | 6 | 172 | 1 | 175 | | |
| 2 | 185 | 7 | 170 | 2 | 187 | 7 | 187 | 2 | 171 | | |
| 3 | 168 | 8 | 185 | 3 | 178 | 8 | 183 | 3 | 185 | | |
| 4 | 182 | 9 | 172 | 4 | 172 | 9 | 186 | 4 | 173 | | |
| 325 | 168 | 350 | 176 | 375 | 174 | 400 | 177 | 425 | 156 | | |
| Total.. | 4,508 | Total.. | 4,380 | Total.. | 4,292 | Total.. | 4,579 | Total.. | 4,534 | | |

## Twenty-four Hour Coal Consumption Test, October 5 and 6, 1908—Continued.

| Bag No. | Total weight. | Bag No. | Total weight. |
|---|---|---|---|
| 1–25 | 4,017 | Brought forward 1–325 | 56,671 |
| 26–50 | 4,216 | 326–350 | 4,380 |
| 51–75 | 4,121 | 351–375 | 4,292 |
| 76–100 | 4,063 | 376–400 | 4,579 |
| 101–125 | 4,491 | 401–425 | 4,534 |
| 126–150 | 4,577 | 426–443 | 3,123 |
| 151–175 | 4,663 | Coal bags | 77,579 |
| 176–200 | 4,563 | Deduct for bags | 886 |
| 201–225 | 4,958 | | 76,693 |
| 226–250 | 4,109 | Coal on floors | 125 |
| 251–275 | 4,181 | | 76,568 |
| 276–300 | 4,204 | Allowance for thicker fires | 568 |
| 301–325 | 4,508 | Total coal | 76,000 |
| Total 1–325 | 56,671 | Tons for 24 hours | 33.92 |

## Twenty-four Hour Coal Consumption Test, October 5 and 6, 1908.

| Averages. | Revolutions per minute. | | | |
|---|---|---|---|---|
| | Starboard. | Center. | Port. | Mean of three shafts. |
| To end of 4th hour | 446.3 | 456.2 | 468.9 | 457.1 |
| To end of 8th hour | 448.4 | 451.1 | 466.7 | 455.4 |
| To end of 12th hour | 446.4 | 450.0 | 461.9 | 452.8 |
| To end of 16th hour | 435.7 | 446.9 | 454.0 | 445.5 |
| To end of 20th hour | 423.2 | 432.2 | 444.0 | 433.1 |
| To end of 24th hour | 457.9 | 457.8 | 476.0 | 463.9 |

Average revolutions of three shafts for twenty-four hours =451.3 per minute.

## WATER TEST.—PROPELLING MACHINERY AND ALL AUXILIARIES.

Start at 2.00 A. M. Temperature of sea 64°. Temperature of water 65°.

| Number of barrel. | Weight, pounds. | Number of barrel. | Weight, pounds. | Number of barrel. | Weight, pounds. |
|---|---|---|---|---|---|
| 5..... | 403 | 5..... | 410 | 5..... | 403 |
| 3..... | 403 | 3..... | 418 | 3..... | 410 |
| 6..... | 420 | 6..... | 412 | 6..... | 418 |
| 1..... | 402 | 1..... | 415 | 1..... | 412 |
| 2..... | 410 | 2..... | 400 | 2..... | 410 |
| 4..... | 395 | 4..... | 421 | 4..... | 418 |
| 5..... | 370 | 5..... | 403 | 5..... | 405 |
| 3..... | 415 | 3..... | 405 | 3..... | 410 |
| 6..... | 420 | 6..... | 415 | 6..... | 405 |
| 1..... | 395 | 1..... | 420 | 1..... | 400 |
| 2..... | 412 | 2..... | 410 | 2..... | 410 |
| 4..... | 330 | 4..... | 430 | 4..... | 385 |
| 5..... | 410 | 5..... | 408 | 5..... | 408 |
| 3..... | 410 | 3..... | 420 | 3..... | 415 |
| 6..... | 423 | 6..... | 430 | 6..... | 410 |
| 1..... | 397 | 6..... | 390 | 1..... | 408 |
| 2..... | 410 | 2..... | 412 | 2..... | 404 |
| 4..... | 330 | 4..... | 356 | 4..... | 430 |
| | 7,155 | | 7,375 | | 7,361 |
| | | | | | 7,375 |
| | | | | | 7,155 |
| Total..... | | | | | 21,891 |

21,891 ÷ 3 = 7,297 × 4 = 29,198 pounds per hour.

Finished test at 2.45 P. M.

Revolutions of turbines.

| | |
|---|---|
| Starboard..... | 445.4 |
| Center..... | 456.2 |
| Port..... | 466.2 |
| Mean revolutions..... | 455.9 |

## WATER TEST.—PROPELLING MACHINERY ONLY.

Start at 10.11 A. M. Temperature of sea water. Temperature of water 85°.

| Number of barrel. | Weight, pounds. | Number of barrel. | Weight, pounds. |
|---|---|---|---|
| 5 | 380 | 1 | 400 |
| 3 | 395 | 2 | 418 |
| 6 | 410 | 4 | 415 |
| 1 | 400 | 5 | 403 |
| 2 | 410 | 3 | 430 |
| 4 | 385 | 6 | 430 |
| 5 | 383 | 1 | 400 |
| 3 | 395 | 2 | 415 |
| 6 | 420 | 4 | 430 |
| 1 | 375 | 5 | 385 |
| 2 | 420 | 3 | 430 |
| 4 | 402 | 6 | 426 |
| 5 | 407 | 1 | 415 |
| 3 | 413 | 2 | 420 |
| 6 | 418 | 4 | 151 |
| | 6,013 | | 5,968 |
| | | | 6,013 |
| Total | | | 11,981 |
| | | | 2 |
| Pounds per hour | | | 23,962 |

Finished at 10.41 A. M.

Revolutions of turbines.

| | |
|---|---|
| Starboard | 443.5 |
| Center | 456.0 |
| Port | 462.9 |
| Mean revolutions | 454.2 |
| Mean speed | 13.022 knots. |

## Speed and Revolutions, Glen Cove, May 20, 1910.

| Number of run. | Speed, knots. | Revolutions per minute, main engine. | Remarks. |
|---|---|---|---|
| 1 | 12.91 | 153.1 | Runs 1 to 12, inclusive, made with center engine only; no propellers on wing shafts. |
| 2 | 13.08 | 152.4 | |
| 3 | 12.94 | 153.7 | |
| Mean of 1, 2 and 3 | 13.002 | 152.9 | |
| 4 | 12.245 | 141.4 | |
| 5 | 12.34 | 145.8 | |
| 6 | 12.60 | 146.9 | |
| Mean of 4, 5 and 6 | 12.381 | 145.0 | |
| 7 | 11.18 | 129.6 | |
| 8 | 11.41 | 128.4 | |
| 9 | 11.12 | 125.9 | |
| Mean of 7, 8 and 9 | 11.28 | 128.1 | |
| 10 | 8.70 | 93.0 | |
| 11 | 8.40 | 96.3 | |
| 12 | 9.30 | 101.7 | |
| Mean of 10, 11 and 12 | 8.70 | 96.8 | |

## STANDARDIZATION OF SCREW OF RECIPROCATING ENGINE, GLEN COVE, MAY 20, 1910. LIST OF PRESSURES.

ENGINE-ROOM OBSERVATIONS.

| Run number. | Elapsed time. | Main steam. | H. P. | I. P. | L. P. | Vacuum. |
|---|---|---|---|---|---|---|
| | *m. s.* | | | | | |
| 1E | | 165 | 155 | 55 | 13 | 27.5″ |
| | 5 4 | 165 | 155 | 55 | 12 | 27.5″ |
| 2W | | 165 | 155 | 55 | 13 | 27.5″ |
| | 5 0 | 165 | 155 | 55 | 13 | 27.5″ |
| 3E | | 165 | 158 | 58 | 14 | 27.35″ |
| | 5 4 | 165 | 158 | 58 | 14 | 27.25″ |
| 4W | | 158 | 125 | 45 | 8.5 | 27.25″ |
| | 5 8 | 158 | 125 | 45 | 8.5 | 27.25″ |
| 5E | | 160 | 139 | 50 | 10 | 27.25″ |
| | 5 18 | 160 | 140 | 50 | 10 | 27.25″ |
| 6W | | 160 | 140 | 50 | 10 | 27.25″ |
| | 5 10 | 160 | 140 | 50 | 10 | 27.25″ |
| 7E | | 165 | 108 | 32 | 3.5 | 27.5″ |
| | 5 53 | 165 | 110 | 32 | 3 | 27.5″ |
| 8W | | 165 | 110 | 33 | 3 | 27.5″ |
| | 5 38 | 165 | 110 | 33 | 3 | 27.5″ |
| 9E | | 160 | 110 | 32 | 3 | 27.5″ |
| | 5 56 | 160 | 110 | 32 | 3 | 27.5″ |
| 10W | | 163 | 56 | 6 | −11 | 27.5″ |
| | 7 37 | 163 | 56 | 6 | −11 | 27.5″ |
| 11*E | | 165 | 60 | 6 | −10 | 27.5″ |
| | 13 15 | 165 | 60 | 6 | −10 | 27.5″ |
| 12W | | 160 | 65 | 11 | − 9 | 27.5″ |
| | | 160 | 65 | 11 | − 8 | 27.5″ |

*Ran beyond mile course. Course, 1.1 knots.

## WATER CONSUMPTION TEST, MAY 20, 1910.—PROPELLING MACHINERY, STEERING ENGINE AND TURBINE GLANDS.

| Starboard side. | | | | Port side. | | | |
|---|---|---|---|---|---|---|---|
| Time, start P. M. | Temperature. | Reading. | Weight, pounds. | Time, start P. M. | Temperature. | Reading. | Weight, pounds. |
| 3–0–0 | | | | | | | |
| 6–45 | 90 | 20 | 2,321 | 3–13–40 | 90 | 21 | 2,292 |
| 20–38 | 90 | 19½ | 2,317½ | 27–33 | 90 | 20 | 2,285 |
| 34–35 | 90 | 18½ | 2,310½ | 41–33 | 90 | 21⅜ | 2,295 |
| 48–15 | 90 | 20⅝ | 2,325 | 54–55 | 90 | 20⅜ | 2,288 |
| 4–1–21 | 90 | 18¾ | 2,312 | 4–8–44 | 90 | 21 | 2,292 |
| 16–3 | 90 | 19 | 2,314 | 23–13 | 90 | 20¾ | 2,291 |
| 30–31 | 90 | 20⅛ | 2,322 | 37–28 | 90 | 20⅝ | 2,290 |
| 44–31 | 90 | 18¾ | 2,312 | 51–35 | 90 | 20¾ | 2,291 |
| 58–58 | 90 | 19½ | 2,318 | 5–6–22 | 90 | 20⅞ | 2,291 |
| 5–13–30 | 90 | 19 | 2,314 | 20–45 | 90 | 21⅛ | 2,293 |
| 28–0 | 90 | 19½ | 2,317 | 35–8 | 90 | 21 | 2,292 |
| 42–13 | 90 | 19 | 2,318 | 49–18 | 90 | 20⅞ | 2,291 |
| 56–24 | 90 | 21 | 2,328 | 6–3–28 | 90 | 20⅝ | 2,290 |
| 6–10–36 | 90 | 19¾ | 2,320 | 17–40 | 90 | 21½ | 2,295 |
| 25–2 | 90 | 18½ | 2,310 | 32–10 | 90 | 20¾ | 2,291 |
| 39–12 | 90 | 19½ | 2,318 | 46–10 | 90 | 20¾ | 2,291 |
| 53–28 | 90 | 20 | 2,321 | 7–0–0 | 90 | 14 | 2,243 |
| Starboard tank | | | 39,398 | Port tank | | | 38,901 |

39,398 + 38,901 = 78,299 ÷ 4 = 19,577 pounds per hour.

## Water Consumption Test, May 20, 1910. Four Hours' Continuous Run at Full Speed. Propelling Machinery, Steering Engine and Turbine Glands.

ENGINE-ROOM OBSERVATIONS.

| Run. | Time, P.M. | Revolutions. | Revolutions per minute. | Main steam. | H. P. | I. P. | L. P. | Vacuum. |
|---|---|---|---|---|---|---|---|---|
| East.... | 3–0–0 | 744,927 | ..... | 165 | 145 | 62 | 13 | 27.0″ |
| | 15–0 | 747,220 | 152.8 | 165 | 155 | 63 | 14 | 26.8″ |
| | 30–0 | 749,515 | 153.0 | 163 | 155 | 63 | 13 | 26.7″ |
| | 45–0 | 751,808 | 152.8 | 165 | 155 | 65 | 13 | 26.8″ |
| | 4–0–0 | 754,100 | 152.8 | 165 | 157 | 65 | 13.5 | 26.9″ |
| | 15–0 | 756,372 | 151.4 | 160 | 153 | 60 | 13 | 26.7″ |
| | 30–0 | 758,650 | 151.2 | 165 | 156 | 65 | 13.5 | 26.9″ |
| | 45–0 | 760,942 | 152.8 | 165 | 157 | 65 | 13.8 | 26.9″ |
| West.... | 5–0–0 | 763,201 | 150.6 | 157 | 153 | 60 | 12.5 | 26.8″ |
| | 15–0 | 765,453 | 150.1 | 160 | 155 | 62 | 13 | 26.9″ |
| | 30–0 | 767,745 | 152.8 | 161 | 155 | 62 | 13 | 26.8″ |
| | 45–0 | 770,050 | 153.6 | 163 | 155 | 65 | 13.5 | 26.9″ |
| | 6–0–0 | 772,355 | 153.6 | 163 | 156 | 65 | 13.5 | 26.9″ |
| | 15–0 | 774,650 | 153.0 | 158 | 153 | 61 | 13 | 26.8″ |
| | 30–0 | 776,943 | 152.8 | 162 | 155 | 62 | 13.5 | 26.8″ |
| | 45–0 | 779,233 | 152.6 | 165 | 157 | 65 | 14 | 26.8″ |
| | 7–0–0 | 781,510 | 151.3 | 165 | 156 | 65 | 13.5 | 26.8″ |
| Average..... | | | 152.25 | 162.5 | 155.2 | 63.3 | 13.3 | 26.8″ |

## Speed and Revolutions, Provincetown, July 14, 1910.

| Number of run. | Speed, knots. | Revolutions per minute. | | | Remarks. |
|---|---|---|---|---|---|
| | | Main engine. | Port turbine. | Starboard turbine. | |
| 1 | 13.698 | 157.5 | 316.0 | 318.6 | Steam to main engine, turbines dragging. |
| 2 | 13.091 | 156.1 | 309.2 | 313.5 | |
| Mean of 1 and 2 | 13.394 | 156.8 | 312.6 | 315.9 | |
| 3 | 14.610 | 161.0 | 487.8 | 500.0 | Direct steam to main engine and turbines. |
| 4 | 14.587 | 161.9 | 523.0 | 530.0 | |
| 5 | 14.730 | 162.2 | 545.3 | 554.4 | |
| Mean of 3, 4 and 5 | 14.628 | 161.7 | 519.2 | 533.1 | |
| 6 | 12.479 | 85.0 | 625.0 | 620.7 | Turbines with main engine dragging. |
| 7 | 13.128 | 89.5 | 628.2 | 635.9 | |
| Mean of 6 and 7 | 12.803 | 87.2 | 626.6 | 628.3 | |
| 8 | 13.636 | 146.1 | 471.1 | 473.0 | Runs, 8 to 19 inclusive under regular steaming conditions. |
| 9 | 13.767 | 147.5 | 478.0 | 474.5 | |
| 10 | 13.550 | 145.6 | 470.4 | 468.1 | |
| Mean of 8, 9 and 10 | 13.680 | 146.7 | 475.1 | 472.5 | |
| 11 | 12.414 | 132.7 | 403.3 | 402.2 | |
| 12 | 12.224 | 132.2 | 402.0 | 402.0 | |
| 13 | 12.566 | 132.1 | 408.1 | 404.1 | |
| Mean of 11, 12 and 13 | 12.357 | 132.3 | 402.6 | 402.5 | |
| 14 | 11.233 | 122.4 | 354.5 | 354.5 | |
| 15 | 12.016 | 124.2 | 362.4 | 361.4 | |
| 16 | 11.201 | 122.6 | 357.4 | 358.3 | |
| Mean of 14, 15 and 16 | 11.616 | 123.3 | 359.1 | 358.9 | |
| 17 | 10.345 | 105.2 | 278.5 | 281.0 | |
| 18 | 9.326 | 105.9 | 276.8 | 277.6 | |
| 19 | 10.390 | 105.2 | 278.2 | 280.7 | |
| Mean of 17, 18 and 19 | 9.847 | 105.4 | 277.6 | 279.4 | |
| 1a | 12.903 | 142.9 | 460.0 | 458.0 | Regular steaming conditions, July 13, 1910. |
| 2a | 13.636 | 144.0 | 462.1 | 459.7 | |
| 3a | 13.383 | 144.2 | 462.0 | 458.0 | |
| Mean of 1a, 2a and 3a | 13.389 | 143.8 | 461.3 | 458.8 | |

## STANDARDIZATION OF SCREW, PROVINCETOWN, JULY 14, 1910.

### LIST OF PRESSURES.

| Run number. | Elasped time. | Main steam. | H. P. | I. P. | L. P. | Vacuum. | | Turbine receivers. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Port. | Starboard. | Port. | Starboard. |
| STEAM TO MAIN ENGINES, TURBINES DRAGGING. | | | | | | | | | |
| 1 S.E. | 4–22–8 | 170 | 167 | 58 | 11.5 | 27.5 | 27.4 | ..... | ..... |
| 2 N.W. | 4–35–0 | 172 | 168 | 60 | 12 | 27.6 | 27.3 | ..... | ..... |
| DIRECT STEAM. MAIN ENGINES AND TURBINES. | | | | | | | | | |
| 3 S.E. | 4–06–4 | 165 | 158 | 57 | 11 | 28.5 | 28.3 | +2 | +2 |
| 4 N.W. | 4–06–8 | 169 | 158 | 55 | 11 | 28.3 | 28.2 | +5 | +6 |
| 5 S.E. | 4–04–4 | 165 | 157 | 55 | 10.5 | 28.4 | 28.2 | +5 | +5 |
| TURBINES WITH MAIN ENGINES DRAGGING. | | | | | | | | | |
| 6 N.W. | 4–48–5 | 167 | 0 | 0 | –26 | 28.3 | 28.1 | +22 | 21.5 |
| 7 S.E. | 4–34–2 | 169 | 0 | 0 | –24 | ..... | ..... | +24 | 24. |
| REGULAR STEAMING CONDITIONS. | | | | | | | | | |
| 8 N.W. | 4–24–0 | 172 | 165 | 65 | 19 | 28.6 | 28.4 | +1.2 | +1.3 |
| 9 S.E. | 4–21–5 | 172 | 165 | 66 | 19 | 28.5 | 28.2 | +1.3 | +1.3 |
| 10 N.W. | 4–25–6 | 172 | 166 | 67 | 18 | 28.5 | 28.2 | +1.2 | +1.1 |
| 11 S.E. | 4–50–0 | 163 | 135 | 46 | 10.5 | 28.2 | 28.0 | –3.2 | –3.1 |
| 12 N.W. | 4–54–5 | 166 | 138 | 45 | 11 | 28.2 | 28.1 | –2.8 | –2.8 |
| 13 S.E. | 4–46–5 | 177 | 137 | 45 | 11.5 | 28.2 | 28.1 | –2.8 | –2.8 |
| 14 N.W. | 5–20–5 | 152 | 114 | 36 | 6.5 | 28.1 | 28.0 | –5.5 | –5.5 |
| 15 S.E. | 4–59–4 | 155 | 114 | 37 | 6.5 | 28.2 | 28.1 | –5.2 | –5.2 |
| 16 N.W. | 5–21–4 | 154 | 115 | 37 | 6.5 | 28.2 | 28.0 | –5.2 | –5.3 |
| 17 S.E. | 5–48–0 | 155 | 82 | 20 | 0 | 27.6 | 27.2 | ..... | ..... |
| 18 N.W. | 6–26–0 | 154 | 81 | 19 | 0 | 27.5 | 27.2 | ..... | ..... |
| 19 S.E. | 5–46–5 | 156 | 83 | 20 | 0 | 27.5 | 27.2 | ..... | ..... |
| PROVINCETOWN, JULY 13, 1910. | | | | | | | | | |
| REGULAR STEAMING CONDITIONS. | | | | | | | | | |
| 1a N.W. | 4–39–0 | 170 | 158 | 60 | 16.5 | 28.5 | 28.2 | +.1 | +.2 |
| 2a S.E. | 4–24–0 | 171 | 159 | 61 | 16.7 | 28.5 | 28.3 | –.1 | –.2 |
| 3a N.W. | 4–29–0 | 170 | 157 | 60 | 16.8 | 28.5 | 28.2 | ..... | ..... |

## Twenty-four Hour Coal Consumption Test.—Regular Steaming Conditions, Run Provincetown to New London, July 14, 1910.

| Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 160 | 31 | 158 | 61 | 160 | 91 | 160 | 121 | 170 | 151 | 170 |
| 2 | 170 | 2 | 160 | 2 | 170 | 2 | 160 | 2 | 190 | 2 | 172 |
| 3 | 165 | 3 | 140 | 3 | 150 | 3 | 175 | 3 | 210 | 3 | 176 |
| 4 | 158 | 4 | 155 | 4 | 165 | 4 | 195 | 4 | 175 | 4 | 185 |
| 5 | 155 | 5 | 150 | 5 | 180 | 5 | 185 | 5 | 155 | 5 | 182 |
| 6 | 165 | 6 | 155 | 6 | 175 | 6 | 180 | 6 | 155 | 6 | 180 |
| 7 | 150 | 7 | 160 | 7 | 200 | 7 | 185 | 7 | 165 | 7 | 175 |
| 8 | 155 | 8 | 185 | 8 | 195 | 8 | 195 | 8 | 175 | 8 | 180 |
| 9 | 158 | 9 | 158 | 9 | 185 | 9 | 185 | 9 | 145 | 9 | 174 |
| 10 | 158 | 40 | 160 | 70 | 175 | 100 | 170 | 130 | 170 | 160 | 175 |
| 1 | 165 | 1 | 155 | 1 | 185 | 1 | 170 | 1 | 200 | 1 | 173 |
| 2 | 150 | 2 | 160 | 2 | 168 | 2 | 185 | 2 | 185 | 2 | 180 |
| 3 | 158 | 3 | 130 | 3 | 190 | 3 | 180 | 3 | 170 | 3 | 195 |
| 4 | 158 | 4 | 160 | 4 | 195 | 4 | 200 | 4 | 165 | 4 | 200 |
| 5 | 182 | 5 | 155 | 5 | 170 | 5 | 205 | 5 | 150 | 5 | 170 |
| 6 | 150 | 6 | 158 | 6 | 190 | 6 | 180 | 6 | 145 | 6 | 190 |
| 7 | 168 | 7 | 170 | 7 | 180 | 7 | 170 | 7 | 150 | 7 | 180 |
| 8 | 170 | 8 | 165 | 8 | 200 | 8 | 185 | 8 | 170 | 8 | 185 |
| 9 | 1 0 | 9 | 160 | 9 | 200 | 9 | 200 | 9 | 145 | 9 | 180 |
| 20 | 180 | 50 | 165 | 80 | 210 | 110 | 190 | 140 | 155 | 170 | 174 |
| 1 | 170 | 1 | 170 | 1 | 200 | 1 | 180 | 1 | 160 | 1 | 176 |
| 2 | 192 | 2 | 165 | 2 | 185 | 2 | 210 | 2 | 150 | 2 | 153 |
| 3 | 150 | 3 | 175 | 3 | 180 | 3 | 175 | 3 | 165 | 3 | 160 |
| 4 | 170 | 4 | 170 | 4 | 200 | 4 | 195 | 4 | 155 | 4 | 180 |
| 5 | 185 | 5 | 152 | 5 | 190 | 5 | 190 | 5 | 162 | 5 | 184 |
| 6 | 160 | 6 | 170 | 6 | 175 | 6 | 170 | 6 | 165 | 6 | 165 |
| 7 | 150 | 7 | 155 | 7 | 170 | 7 | 195 | 7 | 180 | 7 | 190 |
| 8 | 160 | 8 | 160 | 8 | 170 | 8 | 205 | 8 | 180 | 8 | 195 |
| 9 | 155 | 9 | 168 | 9 | 185 | 9 | 185 | 9 | 185 | 9 | 180 |
| 30 | 150 | 60 | 180 | 90 | 150 | 120 | 180 | 150 | 178 | 180 | 185 |
| Total.. | 4,907 | Total.. | 4,824 | Total.. | 5,448 | Total.. | 5,440 | Total.. | 5,035 | Total.. | 5,364 |

## TWENTY-FOUR HOUR COAL CONSUMPTION TEST.—REGULAR STEAMING CONDITIONS, RUN PROVINCETOWN TO NEW LONDON, JULY 14, 1910—Continued.

| Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. | Bag No. | Weight, pounds. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 160 | 204 | 190 | 227 | 175 | 250 | 145 | 273 | 210 | 296 | 180 |
| 2 | 190 | 5 | 180 | 8 | 165 | 1 | 165 | 4 | 165 | 7 | 178 |
| 3 | 200 | 6 | 185 | 9 | 190 | 2 | 160 | 5 | 165 | 8 | 190 |
| 4 | 160 | 7 | 170 | 230 | 205 | 3 | 195 | 6 | 198 | 9 | 188 |
| 5 | 180 | 8 | 170 | 1 | 190 | 4 | 200 | 7 | 175 | 300 | 158 |
| 6 | 190 | 9 | 180 | 2 | 190 | 5 | 170 | 8 | 185 | 1 | 155 |
| 7 | 180 | 210 | 175 | 3 | 175 | 6 | 190 | 9 | 178 | 2 | 182 |
| 8 | 170 | 1 | 180 | 4 | 185 | 7 | 190 | 280 | 182 | 3 | 170 |
| 9 | 195 | 2 | 190 | 5 | 195 | 8 | 190 | 1 | 200 | 4 | 155 |
| 190 | 180 | 3 | 193 | 6 | 195 | 9 | 185 | 2 | 185 | 5 | 175 |
| 1 | 190 | 4 | 185 | 7 | 195 | 260 | 195 | 3 | 170 | 6 | 175 |
| 2 | 190 | 5 | 180 | 8 | 190 | 1 | 190 | 4 | 176 | 7 | 155 |
| 3 | 190 | 6 | 200 | 9 | 205 | 2 | 200 | 5 | 178 | 8 | 170 |
| 4 | 190 | 7 | 170 | 240 | 195 | 3 | 210 | 6 | 150 | 9 | 180 |
| 5 | 180 | 8 | 170 | 1 | 190 | 4 | 210 | 7 | 157 | 310 | 184 |
| 6 | 170 | 9 | 175 | 2 | 185 | 5 | 210 | 8 | 182 | 1 | 188 |
| 7 | 190 | 220 | 170 | 3 | 195 | 6 | 190 | 9 | 178 | 2 | 168 |
| 8 | 190 | 1 | 170 | 4 | 200 | 7 | 195 | 290 | 186 | 313 | 210 |
| 9 | 180 | 2 | 180 | 5 | 170 | 8 | 200 | 1 | 182 | Total.. | 3,161 |
| 200 | 170 | 3 | 195 | 6 | 200 | 9 | 180 | 2 | 185 | | |
| 1 | 170 | 4 | 180 | 7 | 165 | 270 | 200 | 3 | 180 | | |
| 2 | 185 | 5 | 170 | 8 | 180 | 1 | 200 | 4 | 173 | | |
| 203 | 170 | 226 | 175 | 249 | 165 | 272 | 210 | 295 | 186 | | |
| Total.. | 4,170 | Total.. | 4,133 | Total.. | 4,300 | Total.. | 4,375 | Total.. | 4,126 | | |

## Summary Twenty-four Hour Coal Consumption Test. Run Provincetown to New London, July 14–15, 1910.

| Bag No. | Total weight. |
|---|---|
| 1–30 | 4,907 |
| 31–60 | 4,824 |
| 61–90 | 5,448 |
| 91–120 | 5,440 |
| 121–150 | 5,035 |
| 151–180 | 5,364 |
| 181–203 | 4,170 |
| 204–226 | 4,133 |
| 227–249 | 4,300 |
| 250–272 | 4,375 |
| 273–295 | 4,126 |
| 296–303 | 3,161 |
| Coal and bags | 55,378 |
| Deduct for 313 bags | 2,113 |
| | 53,265 |
| Deduct for coal weighed back | 682 |
| Total coal pounds | 52,583 |
| $\frac{52583}{2240}$ = 23.47 tons for 24 hours. | |

| | No. | Weight. |
|---|---|---|
| Coal weighed back in bunker | A | 130 |
| | B | 130 |
| | C | 160 |
| 8 empty bags weighed 54 pounds | D | 145 |
| 1 empty bag weighed 6.75 pounds | E | 126 |
| 313×6.75=2112.75 pounds | | 716 total. |
| Deduct for bags | | 34 |
| Returned to bunkers | | 682 |

## Twenty-four Hour Endurance Run, Provincetown to New London, July 14, 1910.

First 12 hours. REVOLUTIONS. Start 12.30 P. M.

| Time, P. M. | Main engine. | Revolutions per minute. | Starboard L. P. turbine. | Revolutions per minute. | Port L. P. turbine. | Revolutions per minute. |
|---|---|---|---|---|---|---|
| 12–30–0 | 847,992 | | 883,895 | | 486,259 | |
| 1– 0–0 | 852,213 | | 886,605 | | 488,969 | |
| 30–0 | 856,401 | | 889,280 | | 491,640 | |
| 2– 0–0 | 860,627 | | 891,992 | | 494,352 | |
| 30–0 | 864,875 | | 894,727 | | 497,085 | |
| 3– 0–0 | 869,089 | | 897,427 | | 499,788 | |
| 30–0 | 873,308 | | 900,129 | | 502,489 | |
| 4– 0–0 | 877,526 | | 902,836 | | 505,201 | |
| 30–0 | 881,740 | | 905,545 | | 507,907 | |
| 5– 0–0 | 885,929 | | 908,222 | | 510,586 | |
| 30–0 | 890,149 | | 910,952 | | 513,320 | |
| 6– 0–0 | 894,369 | | 913,683 | | 516,053 | |
| 30–0 | 898,604 | | 916,425 | | 518,804 | |
| 7– 0–0 | 902,780 | | 919,083 | | 521,467 | |
| 30–0 | 907,045 | | 921,859 | | 524,248 | |
| 8– 0–0 | 911,287 | | 924,613 | | 527,008 | |
| 30–0 | 915,496 | | 927,325 | | 529,723 | |
| 9– 0–0 | 919,671 | | 929,982 | | 532,393 | |
| 30–0 | 923,903 | | 932,698 | | 525,110 | |
| 10– 0–0 | 928,142 | | 935,420 | | 537,837 | |
| 30–0 | 932,394 | | 938,160 | | 540,582 | |
| 11– 0–0 | 936,651 | | 940,900 | | 543,327 | |
| 30–0 | 940,907 | | 943,642 | | 546,074 | |
| 12– 0–0 midnight | 945,168 | | 946,389 | | 548,827 | |
| 12–30–0 A. M. | 949,447 | 140–91 | 949,147 | 453·2 | 551,592 | 453·7 |

## Twenty-four Hour Endurance Run, Provincetown to New London, July 15, 1910.

Second 12 hours. REVOLUTIONS. Finish 12.30 P. M.

| Time, A. M. | Main engine. | Revolutions per minute. | Starboard L. P. turbine. | Revolutions per minute. | Port L. P. turbine. | Revolutions per minute. |
|---|---|---|---|---|---|---|
| 12–30–0 | 949,447 | ..... | 949,147 | ..... | 551,592 | ..... |
| 1– 0–0 | 953,667 | ..... | 951,826 | ..... | 554,279 | ..... |
| 30–0 | 957,905 | ..... | 954,526 | ..... | 556,984 | ..... |
| 2– 0–0 | 962,135 | ..... | 957,216 | ..... | 559,683 | ..... |
| 30–0 | 966,352 | ..... | 959,880 | ..... | 562,353 | ..... |
| 3– 0–0 | 970,599 | ..... | 962,586 | ..... | 565,065 | ..... |
| 30–0 | 974,855 | ..... | 965,291 | ..... | 567,778 | ..... |
| 4– 0–0 | 979,110 | ..... | 967,999 | ..... | 570,492 | ..... |
| 30–0 | 983,314 | ..... | 970,657 | ..... | 573,153 | ..... |
| 5– 0–0 | 987,516 | ..... | 973,327 | ..... | 575,829 | ..... |
| 30–0 | 991,719 | ..... | 975,004 | ..... | 578,510 | ..... |
| 6– 0–0 | 995,930 | ..... | 978,700 | ..... | 581,213 | ..... |
| 30–0 | 000,143 | ..... | 981,396 | ..... | 583,915 | ..... |
| 7– 0–0 | 004,332 | ..... | 984,072 | ..... | 586,594 | ..... |
| 30–0 | 008,524 | ..... | 986,748 | ..... | 589,276 | ..... |
| 8– 0–0 | 012,763 | ..... | 989,472 | ..... | 592,006 | ..... |
| 30–0 | 016,977 | ..... | 992,178 | ..... | 594,718 | ..... |
| 9– 0–0 | 021,232 | ..... | 994,917 | ..... | 597,463 | ..... |
| 30–0 | 025,495 | ..... | 997,666 | ..... | 600,216 | ..... |
| 10– 0–0 | 029,691 | ..... | 000,350 | ..... | 602,904 | ..... |
| 30–0 | 033,957 | ..... | 003,103 | ..... | 605,661 | ..... |
| 11– 0–0 | 038,226 | ..... | 005,875 | ..... | 608,440 | ..... |
| 30–0 | 042,461 | ..... | 008,612 | ..... | 611,175 | ..... |
| 12– 0–0 noon | 046,715 | ..... | 011,377 | ..... | 613,943 | ..... |
| 12–30–0 P. M. | 050,950 | 140.97 | 014,120 | 451.2 | 616,693 | 452.0 |
| Average for 24 hours | | 140.94 | | 452.2 | | 452.8 |

## WATER CONSUMPTION TEST.—PROPELLING MACHINERY, STEERING ENGINE. RUN POLLOCK RIP TO PROVINCETOWN, JULY 13, 1910.

Start 1–10–0 TANKS.

| Port. | | | Starboard. | | |
|---|---|---|---|---|---|
| Time, P. M. | Column. | Weight. | Time, P. M. | Column. | Weight. |
| 1–25–12 | 22″ | 2,299 | 1–17–52 | 21½″ | 2,331 |
| 1–40–24 | 21¼″ | 2,292 | 1–32–35 | 20¾″ | 2,327 |
| 1–55–34 | 21″ | 2,292 | 1–48– 8 | 19¾″ | 2,319 |
| 2–11– 4 | 21″ | 2,292 | 2– 3–20 | 19½″ | 2,318 |
| 2–26– 8 | 20¼″ | 2,287 | 2–18–40 | 20⅞″ | 2,319 |
| 2–40–30 | 20⅝″ | 2,289 | 2–33–17 | 20⅝″ | 2,317 |
| 2–56– 4 | 21″ | 2,292 | 2–48–22 | 20″ | 2,312 |
| 3–10–33 | 21⅛″ | 2,292 | 3– 3–45 | 20⅜″ | 2,315 |
| 3–24–34 | 19⅝″ | 2,283 | 3–17–17 | 20⅞″ | 2,319 |
| 3–38–50 | 20⅜ | 2,288 | 3–31–24 | 20⅞″ | 2,318 |
| 3–53–50 | 20¾″ | 2,291 | 3–46–25 | 20⅞″ | 2,319 |
| 4–7 –30 | 20⅛″ | 2,285 | 4– 0–43 | 20½″ | 2,315 |
| | | 27,482 | | | 27,829 |

Total water = 27,482 + 27,829 = 55,311 pounds.
Water per hour, 18,698 pounds.

## Water Consumption Test, July 13, 1910.—Propelling Machinery and Steering Engine.

REVOLUTIONS.

| Time, P. M. | Main engine. | Revolutions per minute. | Starboard turbine. | Revolutions per minute. | Port turbine. | Revolutions per minute. |
|---|---|---|---|---|---|---|
| 1–10–0 | 747,817 | | 819,343 | | 422,060 | |
| 40–0 | 752,063 | | 822,028 | | 424,753 | |
| 2–10–0 | 756,309 | | 824,711 | | 427,443 | |
| 40–0 | 760,589 | | 827,438 | | 430,176 | |
| 3–10–0 | 764,806 | | 830,099 | | 432,845 | |
| 40–0 | 769,030 | | 832,765 | | 435,517 | |
| 4–10–0 | 773,291 | | 835,455 | | 438,212 | |
| Average | | 141.5 | | 447.5 | | 448.6 |

## DISCUSSION.

MR. E. H. B. ANDERSON, *Member:*—After the yacht had been in commission a few months we were requested to make an inspection of the turbine machinery, owing to the reason that the coal consumption was exceptionally heavy.

This was done and some of the auxiliary machinery was found to be in need of a thorough overhaul, and the astern turbine throttle valves were also in a leaky condition. No internal examination of the turbines was made, but new propeller wheels were fitted to the shafts.

After these alterations were carried out two coal consumption tests were made, each of 24 hours' duration, and on the second of which 33 tons were consumed.

This would seem to be excessively high when compared with the builders' guarantee, but it should be borne in mind that conditions out here are very different to those which exist on a builder's trial carried out on the Firth of Clyde, and the following reasons can be given for this statement.

(*a*) The quality of coal obtained in New York cannot be compared with good Welsh coal.

(*b*) A coal test of 24 hours is much more severe than any 12-hour test, for one reason, that it becomes necessary to clean all fires at least once, whereas on an 12-hour trial, starting with fine clean fires and burning Welsh coal, cleaning can never be necessary.

There is no question but that the coal consumption would have been reduced by at least 12 per cent. with new propeller wheels, having machined driving faces true to pitch and designed to meet a cruising speed of 13 knots. In addition, the full speed of 15½ knots would have still been available.

In connection with the coal tests, I wish to mention that every possible precaution was taken to obtain accurate data and I feel confident that the recorded figures are reliable. Regular 4-hour watches were the order of the day, with two men on watch in the stokehold at all times.

In connection with the combination arrangement, I consider Mr. Crane is to be highly congratulated on the success he has achieved, and although I was unable to be present on the final trials in July, 1910, I was on board during a preliminary trial in January, at which coal was measured for 36 hours and the data agree very closely in each case.

I now wish to draw your attention to the following: This economical result has been obtained at a certain sacrifice, namely, speed, but of course with the consequent increased cruising radius. I refer to Plate 61 which probably illustrates this point in best manner.

*Curve No.* 1.—Speed and revolutions of reciprocating engine only, with no propeller wheels on wing shafts.

*Curves 2 and 3.*—Speed and revolutions of combination installation, under regular steaming conditions. Curve No. 2 for reciprocating engine; Curve No. 3 for low pressure turbines.

*Curve No. 4.*—Speed and revolutions for the three-shaft arrangement of turbines, as originally installed in yacht.

Now maximum speed, obtained under conditions shown with Curve 1, is 13 knots, with Curves 2 and 3 it is 13.70, whereas Curve 4 is carried out to about 16.25 knots.

COLONEL E. A. STEVENS, *Vice-President:*—May I ask, Mr. Chairman, in view of Mr. Crane's reflection on our old friend The Indicator, how his curves of indicated horse-power were derived? Were the spots obtained by figuring the indicated horse-power from each set of cards or were curves of mean engine power upon revolutions plotted? I have found in running trials that very small differences of wind would make a decided difference in the mean engine power for given revolutions. The same is true of the effect of the rudder if used during run. Plotting separate mean engine power curves for runs with and for runs against the wind, will, I have found, often explain some very puzzling indicator data.

THE CHAIRMAN:—Does any other gentleman desire to add to this discussion?

ADMIRAL H. I. CONE, *Member:*—May I ask a question, that is, will Mr. Crane throw a little more light on the subject as to whether the ship in these tests was run in combination, at a greatly reduced power; this with a view to get the effect of the exhaust reciprocating engine on the turbine at one-tenth of the power?

MR. CRANE:—We never ran at less than ten knots.

ADMIRAL CONE:—I ask this question because these are problems we are attempting to solve—I mean as to the effect when you reduce the power greatly, as we have to do under naval service conditions—in other words, what effect the introduction of a small amount of steam into a reciprocating engine would have on the turbine when it got to the turbine.

MR. CRANE:—I think I can answer that when I come to the general answer.

THE CHAIRMAN:—Does any other gentleman wish to add to the discussion?

MR. George H. BATES, *Member:*—As a matter of record, I would like to call Mr. Crane's attention to the air pump on the high-pressure engine, one air pump in operation at a time. I thought it might be well to mention that.

MR. CRANE:—I will answer this discussion, Mr. Chairman. I had hoped that some of the gentlemen who were present at these tests would express some opinion

as to the care and accuracy with which they were performed. I know there are some others present who were also present at the tests.

In regard to the question of bad coal, our evaporation per pound of coal works out a little better than nine and a half pounds. Now, members of this society may have had much better results with steam coal, even with picked steam coal; I for one have not. I find more tests where the evaporation runs at eight pounds than I do at nine and a half. So far as the speed is concerned there is no question that in making this speed we made a sacrifice of from a knot and a half to two knots of our maximum speed. Whether this could have been avoided is not the question. I think anyone who will look at the sizes of the propellers, the relative pitches, will see that it was perfectly impossible to run at a very much higher speed without overspeeding our center engine, and still have it running correctly for our thirteen knots. We made a trial of allowing live steam to go directly into our low-pressure turbines, and got very close to fifteen knots, but it was not a feasible working arrangement excepting for a stunt.

Now as to economy on very much reduced speed. Apparently, the turbines are doing less and less work as you reduce the pressure on the center engine. You can notice that if you will look at the slip curve on Plate 61. You will notice that at ten knots the turbines are showing ten per cent. negative slip. If, however, you will look at the speed revolution Curves 1 and 2, just above, No. 1 being for the boat driven by the center engine only, No. 2 the revolutions of the center engine when working in combination, you will see that even at these reduced slips the turbines are still helping, and if they did no more than turn around without resistance they still would be of advantage at the regular cruising speed. In this ten-knot condition, there was about 10½ to 11 inches vacuum in the turbine receivers.

In regard to what Col. Stevens said about the indicator cards, the procedure was to take three sets of cards on each run, to figure the cards on the basis of the mean revolutions of the run, plot the individual spots and fair the curve through those spots. Undoubtedly, in the lower speed runs, the low-pressure card is not telling all the truth. I think anyone familiar with indicators will know how difficult it is to touch even lightly on a low-pressure card and not to have it interfere with the action of the indicator.

Perhaps it would not be amiss to have me say that our experience with the vessel in the three conditions has been that in general cruising with adverse weather, with storms, our speed fell off very much more with the turbines than it has since we have had a large propeller to help us out.

The comparative tests were all run in summer weather conditions, smooth sea and clean bottom. In actual service the economy in coal is very much greater than is shown by these results.

MR. GEORGE H. BATES, *Member* (Communicated):—In reply to Mr. Crane's request that one of the members present at the trials of the Vanadis testify to the

accuracy of the tests, I submit the following as one taking an active part in the engine and engine turbine tests.

The coal and water consumption tests were made under average working conditions, the coal being run of mine bituminous coal as obtained in New York Harbor. The firing was done by the yacht's firemen without being coached or interfered with in any particular and as the boilers were steaming easily, they, if anything, neglected the fires. Two fires were cleaned every watch.

In making the water tests, one feed pump delivered the condensed water from the hot well into two tanks; and the drain from these tanks went into the water bottom. These tanks were carefully calibrated and were sloped top and bottom, so as to drain quickly and absolutely, and so that no air could be trapped.

The results, as given, can be duplicated in actual service and probably bettered.

Mr. Crane is to be congratulated on the success of his venture, and on the fact that the tests were made under strictly service conditions.

The President vacated the chair and Vice President McFarland took his place as chairman.

THE CHAIRMAN:—The paper "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member, will now be read by its author.

# SOME SUGGESTIONS FOR REDUCING THE LOSS BY FIRE ON VESSELS.

By Samuel D. McComb, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

In the last few years a number of very valuable papers have been written on the subject of preventing fires on board vessels, but most of them have dealt with cargo fires on steel freight steamers.

It is the intention of this article to offer some suggestions applicable to wooden as well as steel vessels, and to the small as well as the large ones, as it is on the small wooden vessels that fires most frequently occur. Few persons realize the appalling extent of the fire damage to shipping annually, as there are no statistics published showing the monetary loss, and only incomplete and inaccurate reports by the Government and by the different Classification Registers showing the number of vessels and the tonnage lost. However, many lives and millions of dollars in property are lost in flames every year. With a little precaution, most of this loss could have been avoided.

The ideal condition would be to have a vessel constructed entirely of incombustible material and carry only incombustible cargo, but while this, of course, is impossible, the condition can be reached very closely as far as the vessel itself is concerned. The subject of fireproof material has received much consideration, and in recent years the percentage of steel hull vessels has continually increased. Sheet metal and asbestos preparations are replacing wood for interior work, but we are still using wood and other inflammable materials in the construction of our ships, and on account of its cheapness and the fact that it does not require a plant equipped with machine tools, wooden ships will be built for many years to come. They should be constructed so that the probability of their catching fire is reduced to a minimum, and means should be furnished for promptly extinguishing one if it occurred. From the standpoint of fire hazard, vessels can be divided into three general classes, namely, steam, gasoline, and those with no power. The classes will be taken up separately, as the principal causes of fire and the methods of extinguishing them are different in each case.

On steam vessels, the principal ascertained causes of fire are woodwork around uptake or stack igniting, spontaneous combustion of coal, fire originating in the cargo and from galley stoves, lamps and candles. Knowing

how fires originate, we know the points which must be safeguarded to prevent them. It is of the utmost importance where a stack passes through a wooden deck that the opening be cut at least twelve inches clear all around and the wood be faced with asbestos and sheet-iron or steel. If forced draft is used and overheats the uptake and stack, further protection is needed—either the uptake and the base of the stack should be covered with cement or all the woodwork within a distance of three feet should be covered with sheet-iron placed over asbestos. When covering a boiler care should be taken along the sides of it; frequently the space between the boiler shell and bunkers is so small that it is difficult to make a good job, but in no case should this space be packed up with non-conducting material; some opening should always be left between the covering and the bunkers. On a leg boiler, the covering on the sides of the fire-box should be carried right down to the floor; frequently it is stopped about the level of the grate bars, and an examination will show that the heat from the uncovered plates has charred the bunker boards alongside. A coaming should be placed at the front of boilers extending across the fire-room to prevent hot ashes getting between boiler and bunker sides. If the fire-room floor is laid on a wooden deck or wooden beams, asbestos should be put down first. Hot ashes have set fire to a wooden deck through four inches of cement. The same care that is used in protecting woodwork around the boilers should be used around the galley stove and stove-pipes. All wooden partitions in the back and at the sides of all galley stoves should be protected. Where possible the floor should be brick or cement, but, if wood, should be covered with sheet metal over asbestos extending out in front at least 2 feet 6 inches and the stove should be securely fastened down. Most important of all is to have a metal hood over the stove or have the ceiling overhead covered with heavy asbestos, disastrous fires having been started by grease boiling over on the stove and blazing up, setting the woodwork overhead on fire. The stack from the stove should lead outdoors by the most direct route possible; on some old passenger steamers it has many turns and bends before it finally comes through the upper deck. When possible the galley should be on the upper deck, but if placed in the hold care should be taken to run the stove-pipe in such a manner that even though it get red hot it will not ignite the woodwork. In engine-rooms the method of carrying lubricating oils and waste needs attention. It is well to have the supply of oil as small as possible; where there is a large quantity on board the engineers are usually careless and extravagant with it, while, with a small supply, good care is taken to see that none is wasted. This not only saves money for the owners, but less oil is spilled about. All oil-cans should be carried

in metal trays to catch the drip and all wooden shelves on which oil is kept should be completely covered with metal having the edge turned up, and all joints soldered. Large oil-cans should have self-closing faucets. No oil should be kept in partially filled barrels; when a barrel is opened, it should be emptied at once.

Metal receptacles with rolled joints should be provided for carrying waste. It is quite common to carry waste in burlap bags, placed frequently near the oil supply, so that it gets saturated with leaking oil. It appears difficult to impress on engineers the danger from spontaneous combustion from oily waste, though fierce fires are caused by it.

Lamps have been a fruitful cause of fire on ship-board. Glass lamps frequently break or crack, and should never be used. All lamps should have metal bodies and they should be secured in their sockets with clips or some device which will prevent their coming out when the vessel rolls. They should be carried in substantial wall brackets, or suspended from the ceiling, and be well stayed to prevent swaying. It is a custom on many vessels to use common table lamps, which are very easily upset by the vessel striking something or rolling heavily, and their use should be prohibited. Not long ago a steam lighter on Long Island Sound collided with a sailing vessel; the shock upset a table lamp in the house aft. All the crew rushed to the bow to see what damage had been done, and the fire started by the overturned lamp was not noticed until it had gained great headway. The crew were compelled to abandon the vessel, which was totally destroyed. Lamps should always have proper shields to protect the woodwork over them. It is common to see the paint over a lamp scorched and blistered. One may be left burning when no person is around, and a fire start and get beyond control before it is noticed. Owners should impress on their masters the necessity of taking care of lamps properly. Lamp rooms are required by law to be lined with sheet-metal, and in addition to this they should be made absolutely oil-tight on the bottom, and for at least a foot up on the sides; all laps and all nail holes being soldered over, and any openings in the floor for pipes or rods should have a collar or flange around them to prevent leakage of oil.

In the lamp room of a large steamer a 3-inch hole was punched in the floor for the steam extinguisher pipe. An oil barrel in the room sprung a leak, and the oil ran through the opening and spoiled a quantity of wheat in the hold. Had this oil been ignited it is improbable that the vessel could have been saved. When electric lights are used the installation of the wiring and fixtures should receive careful attention. Of necessity the wire runs in many inaccessible places and a fire caused by defective wiring

may be difficult to locate. All wires in the hold, in engine and boiler spaces, where cargo is carried on main deck and outdoors should be in iron conduit; switchboards should be of slate or other non-inflammable material and well clear of the woodwork back of them, and if the bulkhead is wood it should be covered with heavy asbestos or a steel plate or both. The writer has seen on a large passenger steamer a yellow pine switchboard placed against a yellow pine bulkhead; needless to say it started a fire. It is probably impossible to prevent the use of torches in the engine and boiler rooms, but the man in charge should be cautioned to see that they are carefully used and not left about when lighted. Fires from this cause are numerous—in one instance a lighted torch was left hanging on a wooden stanchion; in another instance, on the top of a boiler; again, alongside an oil barrel, and so on. Engineers must be impressed with the necessity of extreme caution in this respect. Though the practise of using torches by the engineers and firemen cannot be prevented, the use of torches and candles by stevedores and cargo trimmers can and should be stopped; only closed lanterns or incandescent lights should be allowed in the hold of a vessel. In parts of the country the labor unions insist that candles be used, but the shipowners should take a firm stand and put an end to the practise.

The most hazardous type of steam vessels and one that for structural reasons always will be dangerous from a fire standpoint is the wooden tug-boat. For ease in maneuvering, to get around docks quickly and to turn in a small space it is desirable to have a tug small; to tow heavy loads and move large vessels it is necessary to have it powerful. The result is a boat as small as can be designed to carry the machinery powerful enough to do the work required, the boiler usually being the largest size that can be installed, and just as close to the woodwork as the law permits. To allow an ample passageway on deck on each side, the house is made narrow—so the boiler is entirely surrounded by woodwork placed as closely as possible to it. To make matters worse, on board the average tug there is a platform or grating over the boiler where wet lines are placed to be dried out. Dirty clothes and overalls are kept there, and frequently even cans of oil. Inside of the house, over the boiler where the ventilation is poor, the heat becomes excessive, and the woodwork around the stack is ignited, or, where there is a tight platform fitted, the bunker sides will catch fire. A large percentage of the tug-boat fires originate in this way, and they could all be prevented if good air space was left all around the boiler, and proper ventilation was provided over it to allow the hot air to escape. Many stack umbrellas have a flange on the

outer edge which projects below the deck coaming, so that the hot air and gases after rising above the coaming must come down again around the flange of the umbrella, as shown on Plate 69.

It is the opinion of the writer that with construction of this kind the hot air and gases come up against the under side of the umbrella, and stay there. In order to provide effective ventilation the lower edge of the flange should be above the upper edge of the coaming, as shown in Sketch B.

The galley stove is generally in a cramped location, and all the woodwork around it should be especially well protected. These are the two points that require most attention in tug-boats, and the smaller the tug the greater the need of care and caution.

Freight steamers are also a hazardous class. There is not only all the danger inherent in the vessel itself, but also the danger from fires originating in the cargo. It is impossible to lay down any set of rules for promptly extinguishing a cargo fire, for both the cargoes and the vessels carrying them are so varied, ranging from a deep-draught steel vessel carrying iron ore in the hold to a shallow-draught wooden river steamer carrying a deck load of cotton; most numerous, though, are general cargoes. For the safety of ships in the event of an injury, water-tight bulkheads are required in the hold and these act as fire walls tending to confine a fire to the compartment in which it starts. Every compartment should be fitted with a pipe running to the pilot-house and air should be drawn from these pipes continuously. A fire starting in the hold could be promptly detected from the smoke issuing from the pipe, which would also show exactly in which compartment the fire was located. In addition, each compartment should be fitted with a steam fire-extinguisher, so that steam could be turned on immediately when the fire was discovered. The cost of installing steam-pipes is small, and at least one should be fitted to every subdivision of the hold; where the length of these exceed 50 feet two steam-pipes should be fitted. That is the best means of effectually extinguishing a blaze below decks, as the steam can reach every portion of the hold and smother it. To attempt to use a hose would necessitate lifting the hatch covers, thus admitting fresh air. This additional supply of oxygen would cause a smouldering fire to burst out and probably get beyond control.

Steam extinguishers cannot be used on the main deck as there is no confined space to hold the steam, nor can lines of hose always be depended upon, as the entire space may be filled with package freight and the fire may start somewhere near the middle of it, being absolutely inaccessible. The best means of extinguishing this is a sprinkler system. Many of the newer boats are so equipped, but most are not. Every vessel carrying cargo

on the main deck should have sprinklers. A poor installation is about as good as none, and when sprinklers are put in they should cover the vessel completely from stem to stern and be placed close together, otherwise a fire might break out at a point not covered by the sprinklers and gain such headway by the time they opened that it could not be controlled. There is an instance of this kind on record. Fires in general cargoes are the most numerous, arising from spontaneous combustion due to overheating, or by chemical action through the mixture of different substances that may have escaped from their packages. It is impossible for the stevedores to know the contents of every package put on board, but where anything is known to be likely to cause fire, it should be placed so that the hazard is reduced to a minimum.

Coal, oil, hay, cotton, jute and hemp all constitute dangerous cargoes, and vessels carrying them should be especially well equipped with fire apparatus.

The finest vessels we have are the passenger steamers, and these are being constructed better, more costly, and more nearly fireproof every year, but the danger of fire is ever present. We see advertisements in the daily papers of certain steamers:—"They cannot sink, they cannot burn;" "absolutely fireproof," etc., but should a fire once get headway, there will be little left of the vessel. On account of their less rigid construction the shallow-draught river steamers cannot stand as severe a fire on board as the deep-draught vessels. They are braced with hog-chains and tie-rods and should the supporting woodwork collapse, the vessel is likely to break in two. Designers and builders of this type of vessel should consider such a contingency when arranging the longitudinal stiffeners.

The government inspection on this class has improved somewhat in recent years and owners are taking more care, but the fact that four passenger steamers were totally destroyed by fire this year in the vicinity of New York alone shows that there is large room for improvement.

There is one type of vessel on which there is no government inspection or supervision whatever, and on which the fire losses have been numerous and heavy, namely, contractor's plants consisting of dredges, pile drivers, floating derricks, drills, etc. While all the general notes on construction given above are applicable to these craft, there are some points of special importance. Usually over the boilers there is a dome built which has slat partitions around for ventilation—these slats are generally made so that the upper side of one is higher than the lower side of the one above it, as shown on Plate 69, with the result that there is very little, if any, venti-

lation. These slats should be arranged as shown on Plate 69, having a clear horizontal space between them. The writer investigated five fires on dredges all occurring within a short time of each other, two of which were on the same dredge, a machine which had just been built at a cost of $100,000. All five fires started in exactly the same way. According to witnesses, there was a slight explosion and instantly the whole dome seemed to be in flame from end to end. In one instance where the fire had been extinguished very promptly, the inside of the dome was scorched all over, but no one place very badly burned, showing that the fire had not started at one point and spread, but that the dome had been ignited all over simultaneously. The deductions drawn were that certain gases escaped either through a leak in the uptake or while firing the boilers, and had arisen to the under side of the dome and remained there, and had then been ignited by a flame from the furnace door while the fires were being raked. Hot air and gases will not descend, and all ventilators and openings made for their escape should be so constructed that this is not necessary. On account of the number of gears, chains, and cables which require slushing or lubricating, the amount of lubricants carried on these machines is usually large and little care or attention is given to where or how they are carried. It is not uncommon to see a number of partially filled barrels of oil standing alongside of a boiler, with perhaps a burlap sack of waste on the deck nearby. When the danger of this is pointed out to the captain he will usually reply that he is too busy to pay attention to such details, or there is no other place on board to carry it, or he may promise to rectify it, and forget it. As a general thing these machines work in isolated places, or where it is difficult to reach them, and if the superintendent or captain is making satisfactory progress the owners will not visit often, and when they do, it will be to inspect the work being done rather than to examine the machine doing it. There are some firms who keep all their property in first class order, and properly equipped, but on the majority of machines there is evidence of carelessness and disregard of the dangers of fire and insufficient appliances to cope with one. In some cases there is not even a bucket with which to extinguish a fire, and if one started it would surely result in a total loss.

Now in regard to fire-extinguishing appliances generally, the most important point to bear in mind is that when these are needed they are needed badly and quickly. Many owners do not realize this, rather considering the equipment they are compelled to install as a legal requirement that must be complied with, and they put the necessary items on board with no regard to where or how they are placed. All vessels should be so

equipped that every part of them can be reached promptly and effectively by fire appliances. It is an easy matter to extinguish a fire in its incipiency, but it gains headway rapidly and in a short time is beyond control of the best apparatus; therefore, every second counts. Fire appliances should be accessible and ready for instant use. The time lost in coupling up a hose which should have been connected may cause the loss of a ship. Approved fire-extinguishers should be carried in every pilot-house and in every galley. When a fire is discovered it is always reported to the man in the pilot-house, and if he has an extinguisher right at hand he can get to the fire and use it at once. A fire starting in the galley, especially from grease spilling on the stove, is always a dangerous one, but if an extinguisher can be used instantly it can probably be controlled. In addition to these, on large vessels, extinguishers should also be carried in the crews' quarters, and on passenger steamers they should be placed in the main saloon and in passageways for use in the event of the draperies catching.

There are many worthless extinguishers on the market, which are sold only because they are cheap, and it is advisable to purchase only such makes as have been tested and approved by the National Board of Fire Underwriters.

It should be borne in mind that an extinguisher is not a fire department, its capacity is limited, and unless used promptly it is not effective. When a fire attains a size beyond the control of an extinguisher, it becomes necessary to use hose. All steam vessels should have a steam-pump and a hand-pump and these should be connected to the same main, the hand-pump for use in case that steam is not up or the steam-pump out of order. In no case, even on the smallest boats, should there be less than two lengths of hose, as the fire might start just at the place where one length was kept, and render it useless. The fire-main should extend to every deck, and the plugs on it should be located not more than 75 feet apart. Vessels of larger size should have a main on each side. The hose should in no case be less than $1\frac{1}{2}$ inches in diameter—on many small boats at the present time 1-inch hose is used, but experience has shown that this is of no practical value whatever. On larger vessels regular $2\frac{1}{2}$-inch corporation hose should be used. Hose should always be kept connected. The law requires this on passenger steamers, but on other vessels it is the regular custom to have it uncoupled, and it is frequently kept in the hold. This is bad for two reasons—first, the hose probably cannot be found when wanted; and secondly, the threads on the pipe will be filled with dirt or painted over, causing delay in connecting the hose after it is found.

In addition to being thoroughly equipped with extinguishers and hose,

all steamers carrying cargo should, as already mentioned, have steam extinguishers in the hold and sprinklers between decks. Passenger steamers should all be thoroughly sprinkled, those having sleeping accommodations having a sprinkler in every stateroom. Thermostats or some type of automatic fire alarm should be fitted. On passenger steamers over 300 feet long, fire walls should be built every 150 to 200 feet, extending from the main deck to the dome. These walls should be constructed of wood at least $1\frac{1}{2}$ inches thick (two thicknesses of $\frac{3}{4}$-inch tongued and grooved wood laid diagonally), covered on each side with at least $\frac{1}{8}$-inch asbestos having sheet iron over it. The openings in these walls should be as few as possible, and should be fitted with regular fire-doors which can be closed instantly.

### GASOLINE BOATS.

Gasoline is, of course, the great hazard on these boats. The vibration caused by the motor in time loosens the joints in the piping and gasoline leaks into the bilge; a certain amount also leaks out at the carbureter. As there is always more or less bilge water in the bottom, unless water-tight bulkheads are fitted there is a film of gasoline floating on the bilge the entire length of the boat, and this, if ignited, will spread fire all over instantly.

Some years ago a firm constructed launches having the tank in the bow with a water-tight bulkhead back of it; holes were bored in the planking on each side of the tank just below the water-line, allowing free circulation of water around the tank, the feed-pipes came out of the bottom and ran along the keel to the engine, which was at the aft end. Forward of the engine was a water-tight bulkhead extending above the water-line, and the entire engine compartment was lined with brass. If there was a cabin on the launch it ended forward of the engine, which was left in the open so that no vapor got inside of the boat at all. This was the safest possible construction.

The tank and the engine should both be in water-tight compartments even though the bulkheads, at each end of the engine, only come up to the floor boards—and the feed-pipe should be run outside the hull. This will prevent leaking gasoline and oils from flowing the entire length of the boat. All cabin-boats should have ventilators to carry off the vapor. Many motor boats are owned by business men who use them only on week ends, so they remain locked up tight from Sunday or Monday until the following Saturday. If any gasoline is escaping the entire cabin becomes filled with a highly explosive vapor which may blow the boat to pieces. Many persons have been killed from this cause, to say nothing of the loss of the boats.

Fires are frequently caused by gasoline cooking stoves. Only such stoves as have been approved by the Board of Fire Underwriters should be installed, and the woodwork around should be protected and no curtains should be hung near them. The main tank on the boat and the tank from the stove should be filled by daylight only and away from a flame of any kind. On motor boats carrying passengers for hire, smoking should be prohibited, as this has caused many disasters.

The problem of extinguishing fires on motor boats is a difficult one, as entire dependence has to be placed on extinguishers. If the draperies or woodwork catch fire, the average approved extinguisher can handle it, but if the gasoline on the bilge water is ignited, and there are no bulkheads, the entire boat will instantly be in flames, and if there is any quantity of gasoline it is doubtful if any motor boat carries sufficient equipment to extinguish it. This year Congress passed a bill in relation to motor boats, one of the provisions being that every motor boat should "carry ready for immediate use the means of promptly and effectually extinguishing burning gasoline." The act does not specify what will do this, but on June 9, 1910, the Department of Commerce and Labor issued a circular in reference to the act addressed to "Collectors of Customs and Others Concerned," and signed by Benj. S. Cable, Acting Secretary, which contains the following paragraph:—

"No specific means of promptly and effectually extinguishing burning gasoline are prescribed. Besides the usual fire extinguishers, suitable chemicals or bags of coarse flour or sand will serve the purpose." Imagine a man, relying on this government circular, taking his wife and children out in a motor boat with nothing but a bag of flour (itself very inflammable) to promptly and effectually extinguish burning gasoline floating on bilge water. The motor-boat departments of several insurance companies held a test at the Buffalo Yacht Club, Buffalo, N. Y., on September 1, to determine the efficiency of the different makes of extinguishers. Plate 65 shows some photographs of the test. A flat-bottomed punt 16 feet long by 4 feet wide was procured, side boards were nailed on and a floor was put in 6 inches above the bottom in which a hole 2 feet square was cut to represent the opening around the engine. The punt was hauled out on shore; for each test 2 inches of water was put in the bottom and a gallon of gasoline poured on it and ignited. Fourteen trials were held, the extinguishers being operated by a fireman detailed by the fire department, and in every instance when the extinguisher was exhausted the gasoline was still blazing. Later three extinguishers used simultaneously failed to extinguish it. In a fire of this kind it is the area and not the amount of gasoline that is the deter-

mining factor. All this test has demonstrated is that 64 square feet of burning gasoline is too large an area for an extinguisher to handle. Another test will be held this winter with a V-shaped tank, and, beginning with a very small area, more and more water will be put in until the exact limit of each type of extinguisher is determined.

It is gratifying to be able to announce that several large concerns are working in their laboratories at the present time to devise a new type of extinguisher to meet this condition.

According to the latest report of the Commissioner of Navigation, there are over 100,000 motor boats in the United States, so that the successful manufacturer will no doubt be amply repaid.

### BOATS WITHOUT POWER.

The hazard due to means of heating and lighting require the same attention on this class as on other classes of boats, but the two principal dangers are fires originating in the cargo and exposure fires. When there is a donkey boiler, steam fire pumps should be fitted, and a hand-pump connected to hose on each end of the boat should always be installed. There should be a liberal supply of buckets with draw lines attached, so that they can be dropped overboard and refilled. Boats of this class are used largely as lighters or transfers; they are moored alongside docks, warehouses or large steamers being loaded or unloaded, and often so surrounded by similar craft that they cannot be moved until the others have first been taken out of the way. They are exposed to any fire that may start around them, and are helpless. A number of disastrous fires of this kind have occurred. The men in charge of all docks should use care in maintaining an arrangement which will permit all the boats to be moved promptly. Plate 6 shows a pier fire which occurred in New York this summer, the loss amounting to a quarter of a million dollars.

Another important point in connection with all types of vessels which should receive more consideration from owners is the care of vessels when laid up out of commission. Too many, especially those which have not been profitable, are simply moored at an out-of-the-way dock and left until wanted again.

All vessels or groups of vessels should be under charge of watchmen day and night to keep off thieves and tramps who have caused so many fires. Whenever possible, boats should be laid up under city fire protection at a place where fire-engines can readily reach them, and the man in charge should know the location of the nearest alarm box. Where a number of boats are laid up together sufficient space should be kept between them,

so that they do not expose each other; 100 to 150 feet is a safe distance. If there is not sufficient room to admit of this, they should be so moored that they can be cast loose readily and taken out of danger. Every winter several boats are burned by a fire starting on one, and this is a loss which is entirely preventable.

On the large and more valuable steamers, steam should be kept on the donkey boiler when the boat is out of commission, permitting the hose and sprinkler system to be in constant readiness for use.

Plate 66 is a diagram showing how one fleet of passenger steamers is laid up every winter. A main is run down the dock and a connection is made from this to each vessel; all hose on board is attached and stretched out on deck. There is no water in these pipes, but there is a valve in front of the office which admits water to the entire system, and a valve at the connection to each steamer.

There are two men on board each boat and a watchman at the office. In the event of a fire eight streams of water can be had readily on any of the boats.

Managers of the shipyards and basins have at the instance of the underwriters given some attention to this point, but there is room for vast improvement. Plates 67 and 68 show lay-up conditions and what little chance there is of saving a vessel if a fire gets going—especially when they are all frozen in.

There has been no attempt in this article to propose any radical innovation but simply to point out that most of the fires we have are easily avoidable and due to lack of sufficient appliances and even more to the negligence of the masters in not keeping their vessels in proper condition, and having frequent fire drills. Owners and managers are largely responsible for this, for if they are willing to allow their boats to be kept in a slovenly condition the masters soon know it, and will let up a little on the crew—the crews also are soon aware of this, and naturally become careless. When a fire breaks out on a boat of this kind there is a scene of wild disorder, no one knowing where to go or what to do. The fire pumps may be out of order or the hose mislaid, and invariably it is the end of the vessel. However, where the management demands and sees that it gets proper upkeep of its boats, things are vastly different. The master realizes that he will be held strictly accountable and the crew know it too. Things are kept where they belong; duties are properly performed, including frequent fire drills. Where this condition exists, the sounding of the fire-alarm brings out a well drilled crew properly equipped, and they invariably get the best of the fire. It is not unfair to hold the owners largely responsible for most of the fires.

For a number of years the fire record of wooden boats on the Great Lakes was very bad; it reached a climax last year when ten vessels were totally destroyed, and the fire loss exceeded half a million dollars. For some years back, different insurance companies had discontinued these vessels, and a year ago it appeared as though practically all of them would. Representatives of the owners and the insurance companies held conferences in New York, Chicago and Cleveland to determine what caused this abnormal record, and how it could be stopped. The conclusion was that boats were insufficiently equipped and the crews too infrequently drilled. Rules were drawn up to remedy this (see Appendix) and certificates granted to those found to have complied with all of them. The principal features of these rules are that the master is required to report once a month that he has personally examined all equipment every week, finding everything in proper condition or making it so,and that he has had at least two fire drills during the month. The masters and the owners know that an inspector may come on board at any port to verify this report, and the insurance on the vessel may become void through the master's neglect, therefore the equipment is there and drills are held. The drop in the fire loss is noticeable this year. There are one hundred and fifty-six vessels all told which have complied with these rules, and this represents a sufficiently large proportion of the wooden freight boats on the Great Lakes to get an average, yet not one boat with a certificate has been lost. Three fires have started, but they have all been extinguished by the crews with partial losses.

In equipping and operating their boats, it is regrettably true that some owners will only do what they are compelled to by law, and will avoid doing that as much as possible; it does not seem to be a difficult matter to evade many things as the Steamboat Inspection Service appears to be incompetent.

It is the opinion of many that the laws relating to the Steamboat Inspection Service should be amended. They should require that all vessels be constructed, equipped, manned and operated in a manner that will thoroughly safeguard human life, and should be so worded, codified and classified that any one with ordinary intelligence referring to them can find what they are looking for and understand it.

This Society, having on its rolls many of the most important shipowners, managers, designers, builders and surveyors in the United States, is probably the body most capable to attempt this, and the writer begs to suggest to the Society that the President appoint a committee to consider the matter, and to make a report at the next meeting.

# APPENDIX.

## AN EXTRACT FROM THE RULES AND REQUIREMENTS OF THE VESSEL REGISTER, WHICH WAS ORGANIZED FOR THE PURPOSE OF ESTABLISHING A STANDARD OF FIRE EQUIPMENT ON VESSELS.

The following requirements are necessary to obtain a certificate for freight steamers:—

### CONSTRUCTION.

SECTION 1. All government rules and regulations relating to the construction, equipment and outfit of the vessel must be complied with.

SEC. 2. All boilers, main steam and auxiliary lines carrying boiler pressure must be thoroughly covered with asbestos or other approved material, and where steam-pipes pass through woodwork they are to be fitted with a proper metal collar or wood protected in an efficient manner.

SEC. 3. All woodwork within 6 inches of boiler at sides or within 12 inches overhead of boiler or steam dome, or within 2 feet 6 inches of uptakes or breeching must be covered with sheet-metal over sheet asbestos.

SEC. 4. Stoke-hold or fire-room floor must be covered with at least 2 inches of brick or cement or other approved material.

SEC. 5. Where smokestack passes through wood deck, the woodwork must be cut away at least 12 inches clear of the outer casing of said stack, and the wood must be faced with a metal collar over sheet asbestos.

SEC. 6. Coal bunkers must be thoroughly cleaned out as often as possible and at least once every sixty days during the season of navigation, making sure that all coal dust and rubbish are removed; special care to be taken in cleaning shelf piece.

SEC. 7. All oil rooms and lamp rooms must be fitted with steam fire-extinguishers and be thoroughly lined with sheet-metal, with all joints, laps and holes made tight.

SEC. 8. All stoves on board must be securely fastened to the deck and have sheet-metal under them extending out all round at least 6 inches in the case of heating stoves and 2 feet on galley stoves, and if stove is within 18 inches of a wooden bulkhead, the bulkhead must be protected with sheet-metal over asbestos. All stove-pipes or stacks where passing through wooden bulkhead or partition must be fitted with proper metal ring, and

have woodwork cut away. Galley stoves to have hoods over them or have the ceiling protected by sheet-metal over asbestos.

SEC. 9. In hold, engine and boiler-rooms, bunkers, in cargo spaces on main deck or other places where cargo is carried and outdoors, all electric wires must be run in iron conduit. All electric wiring and fixtures must be in accordance with the rules of the New York Board or National Board of Fire Underwriters.

SEC. 10. All oil lamps, except hand lanterns, must have metal bodies and be kept in wall brackets well secured or suspended from above and stayed. All lamps must be secured by approved device for holding them in brackets and must have metal shields over them.

SEC. 11. If gasoline, acetylene or other volatile material is used for lighting, heating or cooking, same must be carried and used in accordance with the rules of the National Board of Fire Underwriters.

NOTE:—Discretion may be used as to the thickness of asbestos used, $\frac{1}{4}$-inch stuff where necessary but lighter material may be used in some places. However, nothing less than $\frac{1}{16}$-inch of asbestos shall be used for any purpose; where thin sheets are used same to be lapped so that there shall be no open joints.

## EQUIPMENT.

SECTION 1. Vessel must be equipped with at least one steam fire-pump of a size not less than that required by law, which must be connected to the fire-main.

SEC. 2. At least one hand-pump must be carried, which must be connected to fire-main, and handles for working same must be kept in place. Hand-pumps must be kept accessible and clear of cargo at all times.

SEC. 3. A water-main must be fitted, extending the entire length of ship, at least 2 inches in diameter, connected to steam-pump, hand-pump and to fire-plugs.

NOTE:—Steamers now equipped with $1\frac{1}{2}$-inch main if approved by local steamboat inspector will be passed for 1910, but 2-inch main will be imperative for 1911.

SEC. 4. There shall be at least six fire-plugs located as follows: One in or near boiler-room, one in fantail above deck, one on upper deck aft, one on forecastle deck, one on main deck at after side of forward house, and at least one on main deck about midships, but in no case shall the plugs be more than 75 feet apart.

SEC. 5. Hose to be at least $1\frac{1}{2}$ inches in diameter in shots of not less than 50 feet with proper couplings and nozzles. Two shots of hose to be

kept forward and two aft. One shot forward and one aft must be kept attached at all times, and the other shot forward and aft must be kept accessible and ready to be attached instantly at all times. Wherever a plug has no hose attached it is to be covered with a cap and spanner to be secured alongside for removing cap and attaching hose.

SEC. 6. At least five chemical fire-extinguishers of make approved by the Board of Steamboat Inspectors and in good order to be kept on board at all times and to be located as follows: One each in engine-room, dining-room, galley, pilot-house and passageway forward, all to be accessible at all times.

SEC. 7. All lamp rooms, oil rooms, holds and all coal bunkers when located in hold to be fitted with steam fire-extinguishers and valves for opening same to be easily accessible and clearly marked "Steam Fire-Extinguisher."

If a vessel be over 1,000 tons net register, and have only one hold, it must have two steam fire-extinguishers, one forward and one aft.

NOTE:—Steam extinguishers in bunkers will not be required when objected to by local steamboat inspector.

SEC. 8. All waste to be kept in metal cans provided with spring hinged covers and constructed of heavy material with rolled joints.

SEC. 9. All oil (whether for illuminating or lubricating purposes—except unbroken packages) must be kept in metal tanks which must have metal drip-pans under them and all illuminating oil must be kept in oil room. No open barrels of illuminating or lubricating oil to be carried, and not more than three unbroken packages of oil for the steamer's use to be carried.

### MAINTENANCE.

SECTION 1. Coal bunkers when located in hold to be cleaned thoroughly when laid up at close of season, and no coal to be left in bunkers. Vessel to be thoroughly cleaned and no waste or rubbish left on board.

SEC. 2. No open lights shall be used on board except the customary torches in engine and boiler rooms, signal lights and candles when used for trimming cargo.

SEC. 3. All members of the crew shall be assigned to stations to be taken in case of fire, and fire drills shall be held in voyage about the first and fifteenth of each month of navigation, but in no event less than twice each month. These fire drills are not required in freezing weather. At fire drills water shall be thrown from every attached shot of hose.

SEC. 4. The master shall examine all fire equipment at least once each

week, noting the results on blanks provided for that purpose and mail such blanks properly filled out on or about the first day of each month to The Vessel Register, 64 Wall Street, New York City.

SEC. 5. The master must see that all fire equipment (hose, buckets, fire-extinguishers, etc.) is kept in good shape, and all worn out or defective equipment must be immediately replaced with new.

SEC. 6. The master and chief engineer must see that vessel is kept clean, that no waste or rags, whether dirty or clean, are allowed to lie around. No dirt or rubbish must be allowed to accumulate and if any oil is spilled it must be cleaned up at once.

SEC. 7. When vessel is laid up at close of season, word shall be sent to The Vessel Register, 64 Wall Street, New York City, as soon as possible thereafter. Vessel must be laid up free from specially hazardous exposure and if possible under city fire protection.

## COPY OF REPORT MASTERS OF VESSELS IN THE REGISTER ARE REQUIRED TO SEND IN MONTHLY.

No.....

### MASTER'S MONTHLY REPORT.

*To be filled out and mailed on the first of each month to The Vessel Register, 64 Wall Street, New York City.*

On.....

For the month of.....19....

Have you personally examined the fire equipment each week and found same in good condition?.....

Did you find any defective equipment?.....

What, if any?.....

Have you replaced it with new?.....

| | 1st week. | 2d week. | 3d week. | 4th week. | 5th week. |
|---|---|---|---|---|---|
| Is Fire Pump in working order?..... | ..... | ..... | ..... | ..... | ..... |
| Is Hand Pump in working order?..... | ..... | ..... | ..... | ..... | ..... |
| Is all Hose attached?..... | ..... | ..... | ..... | ..... | ..... |
| Are all Fire Extinguishers in place?..... | ..... | ..... | ..... | ..... | ..... |
| Is all Waste kept in metal cans, and none left lying around?..... | ..... | ..... | ..... | ..... | ..... |

Have you had a fire drill twice during the month, throwing water from every shot of hose?.....
What dates?.....
Has every man a station to go to in case of fire, and does each man know just where to go and what to do?.....
.....
*Master.*
Dated.....
At.....

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## DISCUSSION.

PRESIDENT TAYLOR:—Gentlemen, I would like first to ask the author of the paper what are the four steamers that were nearly totally destroyed by fire in the vicinity of New York in the last year?

MR. MCCOMB:—The Steamer Manhattan, the Redfield, the M. Martin, and the Poughkeepsie.

PRESIDENT TAYLOR:—Now, these examples show what I have said on this floor before, that steamers of well regulated Companies in actual service are not often destroyed by fire. A very unfortunate accident happened here in the East River a few years ago that is still brought unnecessarily to your minds and the minds of the public; that steamer was taken out very early in the season, after being laid off all winter, with a crew that was mostly picked up promiscuously, and she carried a very large number of women and children many of whom lost their lives in the panic that always accompanies a fire. It was a deplorable accident, but it was very exceptional, for the burning of steamers more often occurs when they have been laid up or about to lay up when the crew is reduced and discipline relaxed. The Manhattan was lying at Portland, Maine, waiting for transfer of ownership to go the Pacific Coast; and the Redfield, Martin, and Poughkeepsie, all at least forty-five years old were lying up the Hudson River. I think they had no passengers.

I believe it is improbable that a fire like that of the Slocum can take place on the well regulated lines carrying passengers in the vicinity of New York.

It is practically impossible to make a steamer absolutely fireproof against fire in a cargo, because any fireproof construction that will withstand a cargo fire will

weigh entirely too much for a vessel to carry on its displacement. On land this matter of displacement so important to the naval architect does not trouble the architect of buildings for a foundation on old Earth can be made to carry any weight. But on land right here in the City of New York, as well as elsewhere, can be seen the futility of using heavy steel so called fireproof construction, because when a fire of materials within the building takes place the steel construction, be it as good and heavy as possible, will be twisted, torn and bent until it falls into ruins.

The only surely fireproof building construction is that where the steel portions, uprights and beams, are entirely protected with brick or cement and concrete, like the building in which we are now holding this meeting. Contrast the weight of this structure with the weight that can be possibly allowed in that of a steamboat or steamship.

No steamboat construction that can possibly be borne on the limits of draught of water can stand a fire in cargo on deck, and even steamships with fire in the hold though they reach port are usually flooded and sunk at the wharf by the means of extinguishing the fire.

The naval architect and marine engineer does the best he can with complicated demands and it is not want of thought that prevents his making his work perfect.

I believe the city of New York has the best Fire Department in the world, but with all its facilities on the stable earth, with its general possibility to fight its fire from all sides, property is destroyed and lives are lost. Can it be expected then that there will never be such losses on steamers with the natural difficulties that attend them to say nothing of the greatest difficulty of all, that of controlling human beings in time of excitement and danger?

I have found that the managers of all well regulated lines are most anxious to reduce the chance of loss of life, and in looking up statistics, which I will furnish, I find that including the Slocum disaster, which was most deplorable in every way, and which should never have happened, there are in proportion to the number of persons carried fewer lives lost on our steamers than on our railroads, and more lives lost in the city of New York, with its great fire department and apparatus in the last year than have been lost by fire on our steamers in five years. (Applause.)

Deputy Fire Chief John Kenlon, *Visitor:*—Mr. President and Gentlemen, while listening to the reading of that paper it occurred to me the subject was not of much interest to you. The author, however, has made many excellent points; he has shown a good knowledge of the duties of a fire chief.

The modern tendency is to get all the luxury possible not alone in hotels and dwellings but in the modern steamship. Every device, every possible means is employed to cater to the fancies and the comforts of the public.

Let me ask you, gentlemen of this society, if you have kept pace with architects that construct these modern buildings in providing means of protecting life in steam-

ships; particularly ships plying between here and Europe and other parts of this country? What have you done toward installing apparatus and equipment for the men who go to sea in charge of these ships. Oftimes carrying 2000 people on board loaded with cotton, lumber, and rosin? Such combinations are coming to this port and leaving it every day. Can you tell me of the installation of any apparatus for extinguishing a fire on these ships? I know of none except the steam jet.

We have been called upon to extinguish fires on steamers plying between southern ports and European ports where the only means they had of holding the fire in check, and some very dangerous fires too, was the steam jet.

I see the gentleman who prepared this paper says it is a very excellent means of extinguishing fires. Well I am sorry to differ with him. To my mind it is a very poor means of extinguishing fires.

Permit me to make a suggestion. It occurred to me while sitting back there looking over that paper that a system of piping could be installed reaching into each hold and deck that would be connected with a perforated pipe or sprinkler system. Water pumped directly through such pipes would be a better means of extinguishing a fire than steam; the pipes would also be a good means of locating the fire. At present it is very difficult to locate.

I have in mind a case of a steamship that left this port some time ago with a large crew and 2000 passengers; she caught fire on the passage to Europe; steam was poured into the hold on the fire for 3 days; notwithstanding this the temperature got so high that there was danger of the plates buckling; the captain fortunately thought of drilling through the tunnel and forcing the contents of 5 or 6 cylinders of carbonic acid gas into the compartment; this so reduced the temperature that the ship safely reached port; when the hatches were removed however flames shot up 75 feet. Now I am not an alarmist—this is not said to frighten people.

THE CHAIRMAN:—We have a great many military members you know who are not afraid of anything.

CHIEF KENLON:—They might be afraid of a dangerous fire.

MR. W. I. BABCOCK, *Member of Council:*—Mr. Chairman, there are certain passenger boats on the Lakes—those of the Goodrich Line operating on Lake Michigan from Chicago, for instance—that are fitted with a very complete installation of automatic sprinklers, both in the freight spaces and the passenger spaces, and the latest built steamers of that line are also fitted with fireproof bulkheads, extending right up to the first passenger deck, all openings in which can be closed tight in case the necessity arises, Mr. A. W. Goodrich, the president of the Company, and an esteemed member of this Society, is very much interested in the subject and has made a thorough study of it for many years. This matter is of so much importance and interest, not only to the members of this Society, but to every owner and manager

of passenger carrying steamers anywhere, that I will endeavor to procure from Mr. Goodrich a complete description of what has been done in this line on his latest boat and incorporate it in our proceedings when published.

The Chief is a fine man and a first class fireman, but he is not a Naval Architect, and when it comes to the question of making a vessel fireproof, I think he does not at all realize what it means.

It is a most difficult matter to make a buiding on land fireproof, and it cannot be done by simply using metal construction—the metal must be covered in with concrete or plaster to protect it, the great weight of such material being of course no objection. A skyscraper can be built so that a fire can be confined to one or two rooms, but that is largely because of the small size of the rooms, and a ship can not be built that way. The question of weight is paramount on a ship; the question of subdivision—of dividing the ship into compartments—must be taken into account, as well as the draught of water, the speed, the amount of fuel necessary, and many other things.

MR. A. W. GOODRICH, *Member* (Communicated):—At the request of Mr. W. I. Babcock, I am glad to give the following description of the arrangements used in our latest built steamer for guarding against fire.

The S. S. Alabama of the Goodrich Transit Company, operating from Chicago, on Lake Michigan, was built by the Manitowoc Dry-Dock Company of Manitowoc, Wisconsin, and went into service in June 1910. She is a single screw steel steamer 250 feet keel, 271 feet 6 inches over all, 44 feet moulded beam, 17 feet deep to main deck and 27 feet deep to spar deck, drawing 12 feet 6 inches loaded, and of 2626 gross registered tonnage. She has five decks, orlop, main, spar, promenade and boat, and the hull is divided by seven watertight bulkheads into eight compartments, and the orlop deck is watertight in Nos. 1, 2, 3, and 7 compartments.

The machinery is amidships. There are three Scotch boilers in the hold and a triple expansion engine of 2250 indicated horse-power.

Cargo is carried in the hold below orlop deck forward and on portions of the orlop deck both forward and aft, also on the main deck from the boiler room to within about 60 feet of the bow. The remainder of the orlop and main decks, and all of the other three decks are devoted entirely to passenger accomodations and crew's quarters, there being altogether 129 staterooms for passengers.

Orlop and main decks are of 15 pound steel plate on steel beams. The spar deck is of No. 10 steel plate on steel channel beams and covered with a $1\frac{3}{8}$ inches matched pine deck laid on battens. The remaining decks, houses and partitions are of wood. All floors in quarters on main and orlop decks are of asbestos composition except in the galley, where it is brick, and all partitions are of steel.

The lower freight space, or cargo hold, is divided into two holds, one under the galley and crews mess rooms, and the other aft of bulkhead No. 3, extending to the bulkhead at the forward end of the coal bunker, and below the orlop deck.

There is also one cargo hold between the orlop deck and the main deck, in other words, this portion of the cargo is contained in three steel rooms, all equipped with the automatic dry pipe sprinkler system, which I consider far superior as a means for extinguishing fire originating in the cargo, as against the introduction of live steam, for the simple reason that the use of live steam would injure the entire cargo in the space in which it is introduced; also, unless the room is absolutely air-tight its efficiency is, in my belief, practically nothing. On the other hand the sprinkler places the water directly on the top of the fire and should extinguish it with a minimum loss to the cargo in the ship.

On the main deck, aft of the crew's quarters, forward, there is a steel bulkhead extending across the ship, with small steel doors on either side so that the smoke and draft may be stopped from entering the crew's quarters in the forecastle at the extreme forward end of the ship. We have divided the space on the main deck between this bulkhead and a bulkhead forward of the boiler room into two spaces by a steel bulkhead with large sliding steel doors. The hydraulic elevator in the forward part of the ship is also enclosed in steel doors. The idea of this bulkhead across the main deck is for the purpose of stopping the draft in the event of fire originating in the cargo. In other words, it is impossible for the entire cargo on this ship to become ignited at any one time. The steel bulkhead extends the entire width of the ship, with similar doors in it, forward of the fire room. This is done so that the smoke cannot drive the stokers out of the fire room, as happened in the case of the steamer Atlanta (which fire was under control of the sprinkler system as long as the stokers were able to stay at their work).

The engine room skylight and the space around the smoke stack is of steel, extending well above the hurricane deck. In other words, you can stand on her fire room floor and see the sky. In addition to ample space being allowed around the smoke stack, we have thoroughly insulated the steel casing around the stack, using a material furnished by the Johns-Mansville people, which is filled with air cells, and I must say affords most excellent insulation. The engine room, which has rooms on either side of it for the passengers' baggage, is fitted with wire glass windows set in heavy brass frames, thus making the engine room, itself, from the floor of the ship to the hurricane deck, one steel room without any woodwork whatever. Abreast of the boiler room, on either side, we have fitted a double connection to the sprinkler system so that in the event of fire in any port, connection to the sprinkler system may be had by the local fire department. Owing to the fact that every fire marshal believes in the right to use his own particular standard of hose coupling, we carry on board the Alabama six different fittings, representing the six principal towns on Lake Michigan where she is apt to land, that their hose may be connected. I may add that where these connections are, there is also a large square opening in her bulwarks so that you may enter from the dock side no matter what the condition of the fire may be on the ship, as there is absolutely nothing in this space that can burn.

Her spar deck is of steel. Another steel bulkhead extends across the ship aft of the engine room space, which isolates the purser's office, check room, etc., from the other parts of the main deck. Her after cargo hold is similar to the forward one, with the exception that no freight is stowed below the after orlop deck.

The ship is fitted with about 300 sprinklers, of which there are about 115 in freight spaces and the remainder in various parts of the crew's quarters and passenger accomodations. In the cargo spaces each sprinkler covers from eighty to one hundred and twenty square feet of floor space. Starting with a six inch pipe from the pump the sizes are gradually reduced until the final connection to each sprinkler had itself is a three-quarter inch pipe.

It might be well to call attention to the fact that we have not seen fit to place sprinkler heads in every stateroom as I really believe this to be unnecessary on a ship arranged like the Alabama for the following reasons:

Staterooms that are occupied only by passengers, and having a window opening on a deck, as well as a doorway opening to the inside of the cabin, afford two opportunities to approach the fire, should a fire originate in a stateroom. A fire in a stateroom on a steamer used on comparatively short runs, is almost unheard of. There are but three causes that I can think of that might cause a stateroom fire, two of which the crew would be informed of very shortly by the person starting it having to leave the room, namely, the use of the alcohol lamp, carelessness in smoking, or possibly defective electric light wiring. To guard against fire originating in an unoccupied room we have placed two thermostats in every room, which should give an immediate alarm, and it is impossible for a fire originating in a stateroom to gain rapid headway, owing to the construction of the room, and the athwartship bulkheads, as you know, do not burn very readily. We have abandoned the old fashioned grill over the staterooms, and fitted them with solid panel transoms, which the passengers may open or close at will. We find that as a rule they are kept closed. This also has a tendency to prevent the spread of fire. Where a stateroom is cleaned every day and contains nothing but bedding and towels, you can see that there is very little, in fact nothing, there to start a fire. We have, however, placed a sprinkler head in our inside rooms for the reason that they afford only one opening from which the fire could be attacked by a stream of water. We have also placed a line of sprinklers in the hallways between the inside and outside staterooms. The crew's quarters are all sprinkled for the reason that in these rooms men accumulate clothing and junk of every description, which might possibly permit of spontaneous combustion. We have also placed a sprinkler head under every stairway, and in what is generally called locker spaces, as with the very best of care, employes are apt to accumulate and throw papers, rags, and most anything into them, which in reality should be thrown overboard.

The following is a list of pumps, hose connections, etc., connected to sprinkler system and hose lines:

| | Water. | Steam. | Stroke. | Gals. |
|---|---|---|---|---|
| ENGINE ROOM:— | | | | |
| 1 duplex pump | 7½ | 12 | 12 | 600 |
| 1 Ahren fire engine duplex | 6 | 10 | 8 | 1200 |
| 2 Dean pumps | 6 | 6 | 8 | 180 |
| 3 feed pumps | 6 | 10 | 12 | 390 |
| | | | | 2370 |
| FORECASTLE DECK:— | | | | |
| 1 hand deck and fire pump, 5 x 5 | | | | 50 |
| FANTAIL—MAIN DECK:— | | | | |
| 1 hand deck and fire pump, 5 x 5 | | | | 50 |
| | | | | 2470 |

16 hose connections on Main Deck with ..... 750 feet of hose.
6 hose connections on Main Cabin Deck with ..... 300 feet of hose.
6 hose connections inside Main Cabin with ..... 300 feet of hose.
13 hose connections on Promenade Deck with ..... 650 feet of hose.
6 hose connections inside Cabin Upper Deck with ..... 300 feet of hose.
4 hose connections on Boat Deck with ..... 200 feet of hose.

Total number of feet of 1½ hose ..... 2500

Two 2½-inch Hose Connections on Main Deck with 200 feet of 2½-inch hose with Siamese connection to 150 feet of 3½-inch hose.

We also carry in the galley a number of small paper bags, hung to hooks on the partitions, containing sand, mixed with a little starch to keep it from caking, for use in case grease boils over and takes fire.

The real advantage of a portable hand pump over a chemical fire extinguisher is this, that in the event of your chemical working, after you have discharged its contents it is then useless until it has been recharged, which under the most favorable circumstances, requires some time. On the other hand the portable hand pump can be filled while it is being operated, by a man carrying water to it in a bucket so that the stream from it may be kept constantly working. These pumps should be equipped with extra long hose so that the pump may always remain on the floor, and if necessary for a man to stand on a ladder, chair or box, he will have sufficient hose to reach. The Alabama is equipped with twenty-four of these portable hand pumps, distributed in easily accessible locations.

PRESIDENT TAYLOR (Communicated):—Supplementing my remarks in the discussion of this paper I now add the statistics to which I referred. It is to be noted that previous to 1908, no record was kept of the lives lost at fires in the city of New York.

## MEMORANDA FOR FIVE YEARS ENDING DECEMBER 31, 1909.

INFORMATION TAKEN FROM PUBLISHED ANNUAL REPORTS OF SUPERVISING INSPECTOR GENERAL OF STEAMBOAT INSPECTION SERVICE, INTERSTATE COMMERCE COMMISSION, STATISTICS OF RAILWAYS, AND FIRE DEPARTMENT OF THE CITY OF NEW YORK.

| | A | B | C | D | E | F | G | H | I | K |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total number of passengers reported. | Number of passengers lives lost on vessels burned. | Proportion of B : A. | Total number of passengers lives lost. | Proportion of D : A. | Total number of fires. | Fires at wharf, etc. | Fires en route | Proportion of G : F. | Number of vessel certificates granted. |
| | *a* | *b* | | *c* | | *a* | | *d* | | |
| Steam vessels, motor boats, etc.. | 1.740,721,495 | 7 | 1:248,674,499 | 538<br>341 | 1:3,235,541<br>1:5,104,755 | 521 | 416 | 105 | 80% | 38.974 |
| Railroads of United States..... | 4.192,167,915 | —— | —— | 2140 | 1:1,958,957 | —— | — | — | —— | —— |
| City of New York | 1908—Killed at fires, 7 firemen, 77 others=84<br>1909—Killed at fires, 3 firemen, 71 others=74<br>1910—Killed at fires, 6 firemen, 63 others=69 | | | | On vessels burned. | 1907—Lives lost, 7 passengers and 16 crew=23. (9 by explosions.)<br>1908—Lives lost, 0 passengers and 19 crew=19. (13 by explosions.)<br>1909—Lives lost, $\frac{0}{7}$ passengers and $\frac{8}{43}$ crew $= \frac{8}{50}$. | | | | |

*a*. Number reported by vessels required by law to make report. It is estimated by the authorities that at least 70 per cent. more passengers were carried by vessels *not* required by law to report.

*b*. Of these 7, 1 death was caused by explosion of fuel oil in furnace on vessel at wharf; 4 deaths were caused by explosion on motor boat caused by dropping lantern in bottom of boat; 2 deaths on steamers en route—fire in freight on main deck.

*c*. Of 538 lives lost, 197 were by accidents, suicides, etc., for which inspection or condition or construction can not be held accountable.

*d*. Of 521 fires, 55 vessels were destroyed en route. Many of the others reported "slight damage," quickly put out," etc.

N. B. Since the above was prepared there has been published a report that during the year 1910, 376 persons were killed and 930 were injured by vehicles in the City of New York. 158 were killed by horse vehicles, 114 by trolley cars and 104 by automobiles. Of these, 196 were under fourteen years of age.

Any suggestion toward making steamers safer from destruction should be gladly received and considered by the Members of this Society, but we should carefully avoid being alarmists.

Criticisms are often made of the United States Steamboat Inspection Service, for like other human endeavors their efforts are sometimes imperfect; but it must be remembered, to their credit, and to the credit of the officers and crews, that comparative records of many years clearly show a remarkable degree of safety for the passengers and crews on our steam vessels.

Crossing the streets of our city is more dangerous than traveling on our steamers.

Mr. SAMUEL D. MCCOMB, *Member* (Communicated):—President Taylor has made a mistake which I should like to correct. He states that the four passenger steamers I named as burning in the past season were all laid up when they burned. This is incorrect, the fact being that all four were in commission, and they were all running and carrying passengers when the fires started. No lives were lost, as the steamers were promptly run into docks and everyone taken off in time. It is fortunate that in most cases where a vessel catches fire, it is possible to make some nearby dock and allow everyone to escape—or when at a distance from land, that there is usually time to get in the boats, which accounts for the small loss of life by fire in comparison with the loss caused by marine disasters.

The writer has dealt with over six hundred losses on vessels and finds that the majority of fires start while vessels are in commission—the most notable exception being small tugs which usually burn while locked up for the night with fires banked.

The following figures are taken from the records of the Bureau of Navigation, Department of Commerce and Labor.

| Fiscal year ending Jun 30. | Number of steam merchant vessels totally destroyed from all causes. | Number of steam merchant vessels totally destroyed by fire. | Number of lives lost on vessels totally destroyed from all causes. | Number of lives lost on vessels totally destroyed by fire. |
|---|---|---|---|---|
| 1906 | 128 | 53 | 308 | 12 |
| 1907 | 149 | 56 | 441 | 48 |
| 1908 | 115 | 58 | 369 | 5 |
| 1909 | 122 | 57 | 378 | 16 |
| 1910 | 190 | 93 | 347 | 23 |
| Total | 704 | 317 | 1843 | 104 |

It will be noted that the loss of life given in this table is only that which occurred on vessels which were totally destroyed, and it is probable that the loss of life on vessels which were only partially destroyed is equally as large. Figures are not

available prior to 1906, but if we include the number lost on the Steamer General Slocum in 1904, which was 957, it would bring the average number of lives lost by fire on vessels for the last seven years up to about 200 a year. This is only on the merchant vessels of the United States. It will be noted that of 704 steam vessels lost in the last five years, 317 were by fire, showing that nearly as many steam vessels are destroyed by fire each year as by sinking, stranding, collision and all other marine perils combined.

I do not want to criticize Steamboat Inspectors at all, as I have the highest regard for all those whom I know, but the Steamboat Inspection Laws under which they are compelled to work are in many respects absurd and antiquated, and in my opinion need revision. I believe this could be best done by a committee of members of the Society, and I sincerely trust that the Society will take the question up and at least make a thorough investigation of it.

Approximately the loss by fire on American vessels every year is 200 human lives—200 vessels of all descriptions, including 60 steamers and much valuable cargo, the monetary loss being about $4,000,000, the problem of reducing this is worth most serious attention.

THE CHAIRMAN:—Gentlemen, I am sure that in your behalf I can extend your thanks to Mr. McComb for his very interesting paper, which has brought out also a most interesting discussion.

President Taylor resumed the chair.

THE PRESIDENT:—Gentlemen, the last paper before this meeting is the paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.

Mr. Page read the paper.

# TWO MARINE INSTALLATIONS OF PRODUCER GAS.

By Charles B. Page, Esq., Member.

[Read at the eighteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 17 and 18, 1910.]

Last year the members of the Society had the pleasure of listening to an article on "The Producer Gas Boat Marenging," by Mr. H. L. Aldrich. The profession as well as vessel owners are deeply indebted to Mr. Aldrich for taking the first step toward what must shortly be a very extended use of producer gas power on shipboard.

While the Marenging was but forty feet in length and powered with a twenty-five horse-power plant, the practicability of marine producer gas power was amply demonstrated at least for small powers. The next boat to be fitted with producer gas was the auxiliary Geodetic Survey Yacht Carnegie. The power plant consisted of a 150 horse-power anthracite coal producer and a four-cylinder, four-cycle, regular type marine engine adapted to the use of producer gas by enlarged inlet and exhaust valves and passages and increased compression. Both producer and engine were constructed largely of nonmagnetic materials and were especially notable because of this fact. The Carnegie has been in commission since the summer of 1909, has made one round trip across the Atlantic, is now in the southern hemisphere, and is expected shortly to go to Australia.

The next installations of marine gas power, so far as I am informed, were made in the power boats Mary A. Sharp, operating on Chesapeake Bay and tributaries, and the Superior, of Bayfield, Wisconsin. Illustrations will be found on Plates 71 to 75. These two boats are the first commercial craft, certainly of any size, in America to be powered with producer gas.

Their principal dimensions are as follows:—

MARY A. SHARP.

| | |
|---|---|
| Length over all | 66 ft. |
| Beam | 14 ft. 6 in. |
| Depth of hold | 5 ft. 3 in. |
| Producer— | |
| Diameter of shell | 4 ft. |
| Height | 6 ft. 10 in. |
| Engine, three-cylinder | 75 B. H. P. |
| Bore | 9 in. |
| Stroke | 12 in. |

Air starting and reversing and direct connected to propeller shaft.
Propeller, 3-blade—

| | |
|---|---|
| Diameter | 44 in. |
| Pitch | 56 in. |

SUPERIOR.

| | |
|---|---|
| Length over all | 65 ft. |
| Beam | 12 ft. 9 in. |
| Depth of hold | 4 ft. |
| Producer— | |
| Diameter of shell | 3 ft. 6 in. |
| Height | 6 ft. 6 in. |
| Engine, two-cylinder | 50 B. H. P. |
| Bore | 9 in. |
| Stroke | 12 in. |

Air starting, fitted with reverse gear.
Propeller, 3-blade—

| | |
|---|---|
| Diameter | 40 in. |
| Pitch | 54 in. |

The same general description will cover the interesting points of the power equipment of both boats. The producers used in both installations are the same type and make as fitted in the Marenging and Carnegie. The producer as shown in the photograph is a cylindrical steel shell lined with asbestos and fire-brick to such a thickness that, when running at full load, the heat radiation is not important. While the shell is rather warm to the touch, it cannot be regarded as hot. With proper ventilation this heat in summer is not objectionable, while it is most agreeable in other seasons of the year. The whole principle being one of suction or vacuum, there is no escape of gas into the boat. The writer has been aboard the Mary A. Sharp after she had been closed up for a week, excepting about half an hour every other day when a little additional draft was given to the producer to keep the fire alive, and found no odor of gas in the engine-room. At a suitable distance above the bottom to form an ash-pit is located the grate and on a line with this are two fire-doors for slicing the fire and raking off the ashes. An ash-pit door is fitted for the removal of ashes and clinkers. The coal is fed into the producer through a hopper on top, and just below, reaching into the center, is the gas take-off pipe. The side walls of fire-brick are substantially vertical and we have then a fire-

brick lined cylinder filled with anthracite pea coal in various stages of combustion. While operating, the hottest fire zone is from six to eighteen inches above the grate. Above this is a red hot and black hot layer of coal extending up to the take-off pipe. The top of the producer is effectively insulated by a considerable layer of coal around and above the take-off pipe. Thus it will appear that the producer itself is extremely simple.

Contrary to general land practise there is no water vaporizer whose function is to generate steam vapor which, mixed with the air and passed through the fire, serves the double purpose of enriching the gas (the steam forming water gas) and softening the clinker. A number of attempts have been made to incorporate this device with marine producers but without success, owing to the deposit of salt and the effect on the vaporizer of the rolling and pitching of the vessel. It is in fact a mooted question whether the presence of considerable water gas is not a detriment rather than an assistance to a smooth-running engine. This being the case, it is only necessary to find a substitute for steam for the softening of the clinker. Exhaust gas introduced under the grate has this effect. The exhaust line from the engine is accordingly tapped and a portion of the exhaust by-tapped to the producer. To keep the ashes and the bottom of the producer cool a small quantity of water is run into the ash-pit, say fifty drops per minute on a seventy-five horse-power producer. Such steam as is formed from this small amount of water of course is turned into water gas and assists slightly in keeping down the clinkers.

With proper care the grate should last two years or more as the best operating conditions require a layer of ashes between the grate and the hottest fire zone. The fire-brick lining is good for three to five years according to usage and the skill of the operator. Relining is comparatively inexpensive.

The gas is taken off near the top of the producer through a two-way water-cooled valve, one outlet to the scrubber, and the other to the purge stack. The latter carries off the gases from the producer when the engine is not drawing same through the scrubber. The purge pipe should be of sufficient height to induce enough natural draft to keep the fire alive when standing by for long periods—weeks if desired. The purge pipe is most conveniently run into a dummy stack which may also contain the exhaust mufflers. The scrubber, whose function is to cool and clean the gas, is shown in the photograph of the Mary A. Sharp located on the top of the engine-room house and aft the stack. It is of the static type, is cylindrical in shape, and fitted with baffles, each section being provided with three water sprays. The material is copper and monel metal to withstand the effect of salt water from the sprays and sulphuric acid from the gas.

The operation of the producer is exceedingly simple and mechanically and chemically similar to that of the self-feeding parlor stove. In starting a new fire, a few bushels of shavings and charcoal (preferred) or wood are thrown on the grate. As soon as this is lit off the fan is started, giving a gentle blast to the fire. Coal is then fed through the hopper until the producer is full. Very frequently good gas of sufficient volume to operate the engine can be obtained in thirty minutes. The coal on the grate is burned to complete combustion ($CO_2$). This gas is reduced to CO on passing through the red and black hot fuel zones above. The fire can be kept for months at a time and the producer is capable of being operated continuously for long periods without shutting down the engine, the removal of the ashes and poking down the clinker being done while the engine is in full operation, and this without any serious fluctuations in the quality of the gas and consequently the speed of the engine. The entire system of producer, scrubber and piping while the engine is operating is under vacuum, the suction of the engine inducing a draft in the producer proportional to its speed or power requirements.

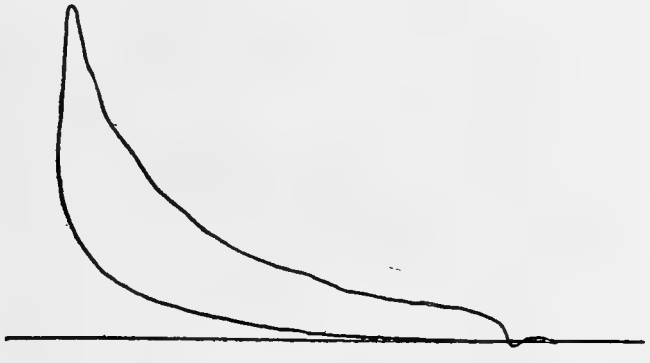
On a plant of the size of the Mary A. Sharp, it takes about thirty minutes to clean the fire in the morning, that is, poke down the clinkers, rake out the ashes, and fill the producer with coal. With a small (two horse-power) auxiliary engine for running a blower, it takes about ten to fifteen minutes to get up gas, a total of three-quarters of an hour from the time the engineer steps aboard until he is ready to get under way. On long trips the fire should be sliced on the grate and poked from the top every hour. Once an hour is often enough to charge with coal. On short runs of an hour, or an hour and a half, no poking is necessary.

Perhaps the most interesting feature of these two installations is the engine. It is two-cycle in principle, in that an explosion is effected in each cylinder each revolution, scavenging in action and substantially equivalent to the four cycles in efficiency. The commercial use of producer gas on ship-board involves the vital questions of weight, space, first cost, and simplicity. The two-cycle principle naturally appeals to the imagination of the marine engineer as fulfilling these requirements more easily than the four-cycle provided it can be made economical and reliable. In land practise we know of the Koerting two-cycle engines which are economical on full loads. Now a marine engine is operated at full power continuously. Hence it is evidently possible to fulfil the specifications for economy. Reliability is a matter of careful design, good material and workmanship, and high grade ignition devices. If the use of a four-cycle engine is made difficult by reason of its weight, space required and first cost, the two-cycle engine should make marine producer gas power installations commercial.

The engines, as stated, are two-cycle. The explosive charge after xpansion is completely blown out by a charge of air before the gas is admitted to the cylinder. The admission of the latter is so timed that none of the gas is lost through the exhaust ports. This gives a clean charge of great power and efficiency, and without any possibility of back-firing. Producer gas is particularly susceptible to back-firing, due to its slow burning, and in eliminating all back-firing in the type of engine described a decided forward step has been made. The saving in heat losses and in friction due to an explosion every revolution in each cylinder compensates in large part for the loss in the air and gas compressors. The working cylinders are of the ordinary construction but with exhaust ports extending around the entire circumference of the cylinder. The exhaust gases pass with the utmost freedom from the cylinders to a large water-jacketed exhaust manifold. Differential pistons and cylinders are used as gas pumps. The downward stroke of the piston induces direct suction on the producer compressing same into a receiver on the upward stroke. This receiver communicates with the cylinder heads and the air and gas valves controlling their admission. Air only is drawn into and compressed in the base and of a volume of about fifty per cent. in excess of both the working piston displacement and the clearance in the combustion chamber. Both air and gas are admitted to the cylinder through mechanically operated valves and are so timed that such a proportion of the air as is intended for scavenging is first admitted, blowing out the burnt gases. The gas valve is then opened, admitting gas direct to the cylinder and mixing with the balance of the air from the base.

The trials of the Mary A. Sharp were quite exhaustive and some interesting data were secured. Tests for horse-power were made on June 23 and 24, each run being about eight hours. Indicator cards were taken every half hour.

The card reproduced as follows was taken at practically full power:—



| | |
|---|---|
| Compression | 135 lbs. |
| Maximum pressure | 275 lbs. |
| Revolutions | 300 |
| M. E. P | 56.2 |
| Indicated horse-power | 97.5 |

On July 14 and 15 a non-stop run of eighteen hours was made from Baltimore to Sharps Wharf on the Rappahannock River. Careful records were made of distances, revolutions, and coal consumed. Following is the condensed log of the trip:—

*July* 14:—

7.48 A. M. Started to blow fire (using hand blower) after two nights lay over.
8.20 A. M. Left dock.
8.36 A. M. Arrived at coal dock. Took on ten tons of coal.
10.42 A. M. Left coal dock.
11.00 A. M. Arrived at oil dock. Took on one barrel of gasolene for canning factory.
11.14 A. M. Left oil dock.
1.55 P. M. Passed Sandy Point.
6.43 P. M. Passed Cove Point.

*July* 15:—

1.33 A. M. Passed Windmill Point.
5.30 A. M. Arrived at Sharps Wharf. Cruised around the river.
6.00 A. M. Tied up and closed draft on producer.

Weather favorable for entire trip with light variable winds. Course steered during the night not a true one owing to compass not being adjusted. Distance from oil dock to Sharps Wharf approximately 155 miles, but probably covered 160. No stop was made for any cause whatever.

| | |
|---|---|
| Blowing up fire | 32 min. |
| Actual running time | 19 hrs. 15 min. |
| Stand-by | 2 hrs. 25 min. |
| Average revolutions | 234.5 |
| Average indicated horse-power | 60.8 |
| Indicated horse-power hour (allowing 40 per cent. for blowing up fire and standbys) | 1,246 |

| | |
|---|---|
| Coal burned (allowing 74 pounds to fill producer at end of trip) | 1,408 lbs. |
| Coal per indicated horse-power | 1.13 lbs. |
| Weight of engine complete, approximately | 9,500 lbs. |
| Weight of producer | 6,000 lbs. |
| Total | 15,500 lbs. |
| Weight per B. H. P. (75 B. H. P. commercial rating) | 205 lbs. |
| Economy of space is important, the length of engine and producer room being but | 13 ft. 3 in. |

No particular economy or horse-power tests were made on the Superior. She is used as a fish-runner out of Bayfield, Wisconsin, collecting fish among the Apostle Islands. This service is probably the most severe that a producer plant can be subjected to as it is constantly stopping and starting. Some ten to fifteen wharves are made in the course of the day with stops of from five to thirty minutes.

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## DISCUSSION.

MR. H. A. EVERETT, *Member* (Communicated):—I should like to say a word with reference to the curve of indicated horse-power on revolutions per minute shown on the last plate of Mr. Page's paper. This curve is radically different from any similar curve previously published and is, I think, open to serious question. The commonly accepted theory of the propeller (Froude's) for screw propelled ships gives us the fact that the indicated horse-power is proportional to the cube of the revolution per minute, at least approximately, but the curve here shown has the indicated horse-power proportional to the first power of the revolution per minute, a straight line, in fact; and in view of its peculiarity it would seem desirable for Mr. Page to indicate the experimental points used in plotting the curve.

MR. PAGE (Communicated):—I have noted Mr. Everett's comments on the horse-power curve shown on Plate 75. His point is undoubtedly well taken.

A very considerable number of indicator cards were taken, ranging from 210 to 300 revolutions per minute. These when plotted averaged up about as shown on plate. Had cards been taken at lower speeds, the general character of the horse-power curve would undoubtedly have shown up as suggested by Mr. Everett.

THE CHAIRMAN:—I will tender to Mr. Page your thanks for an article on a very interesting subject.

We are now at the close of this part of our meeting. We will actually close the meeting to-night in the Astor Gallery of the Waldorf Astoria, at our annual banquet, and I sincerely trust I will meet each and every one of you there. The returns at the present time indicate that there will be the largest number in attendance that we have had at any of our banquets, and the provision for accommodations must be made now because there is very little time left for that purpose. I think you will agree with me that we have had two pleasant days, and I am quite sure that the evening will be equally as pleasant.

The meeting stands adjourned.

# Deaths, 1910.

William T. Powell.

Sullivan W. Robinson.

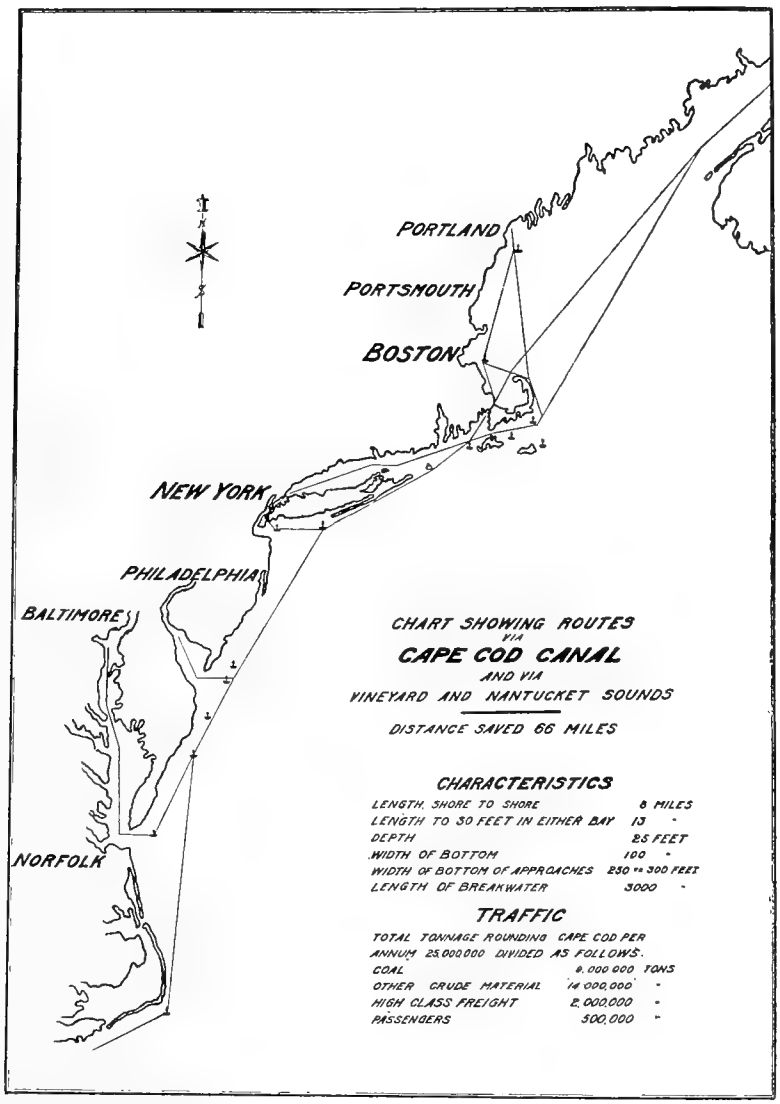
Charles R. Roelker.

Horace See.

Nathan P. Towne.

Frederick M. Wheeler.

*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President.*



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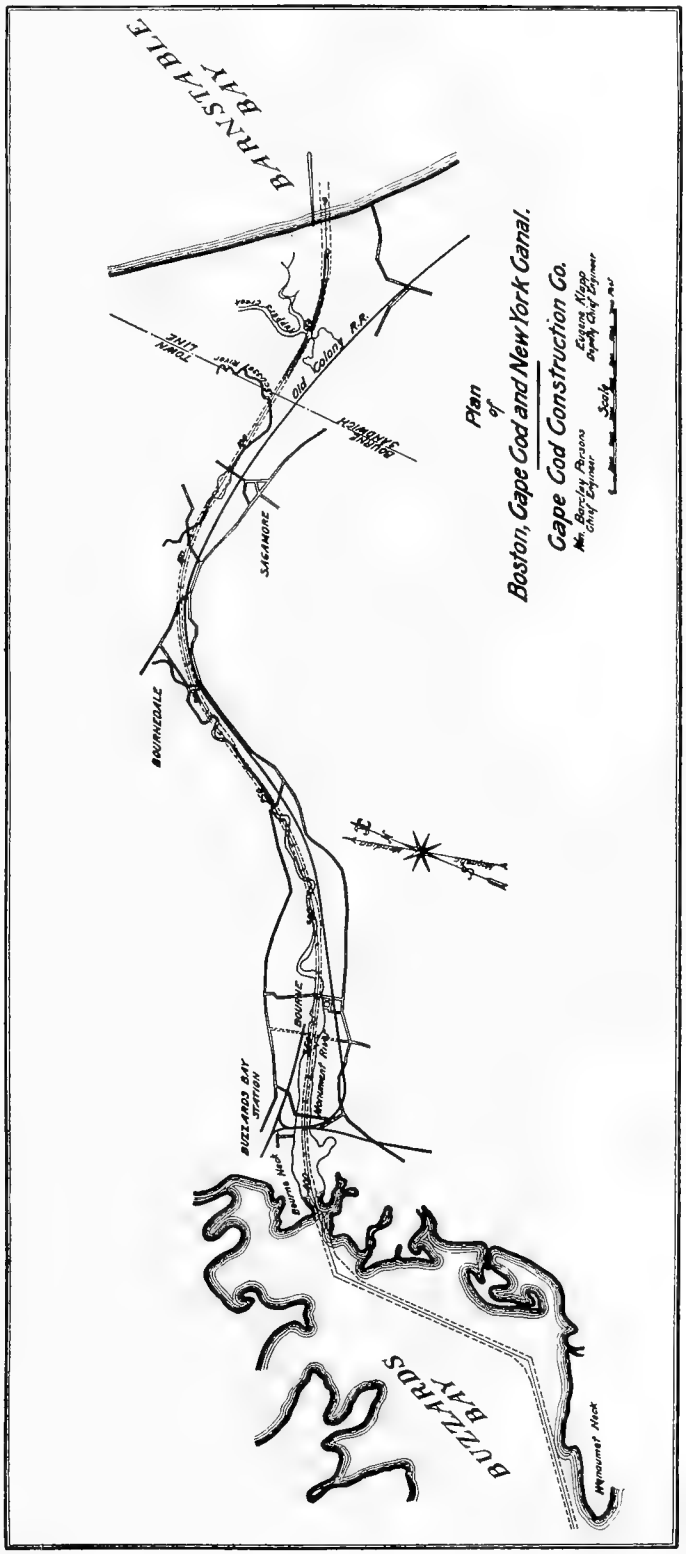
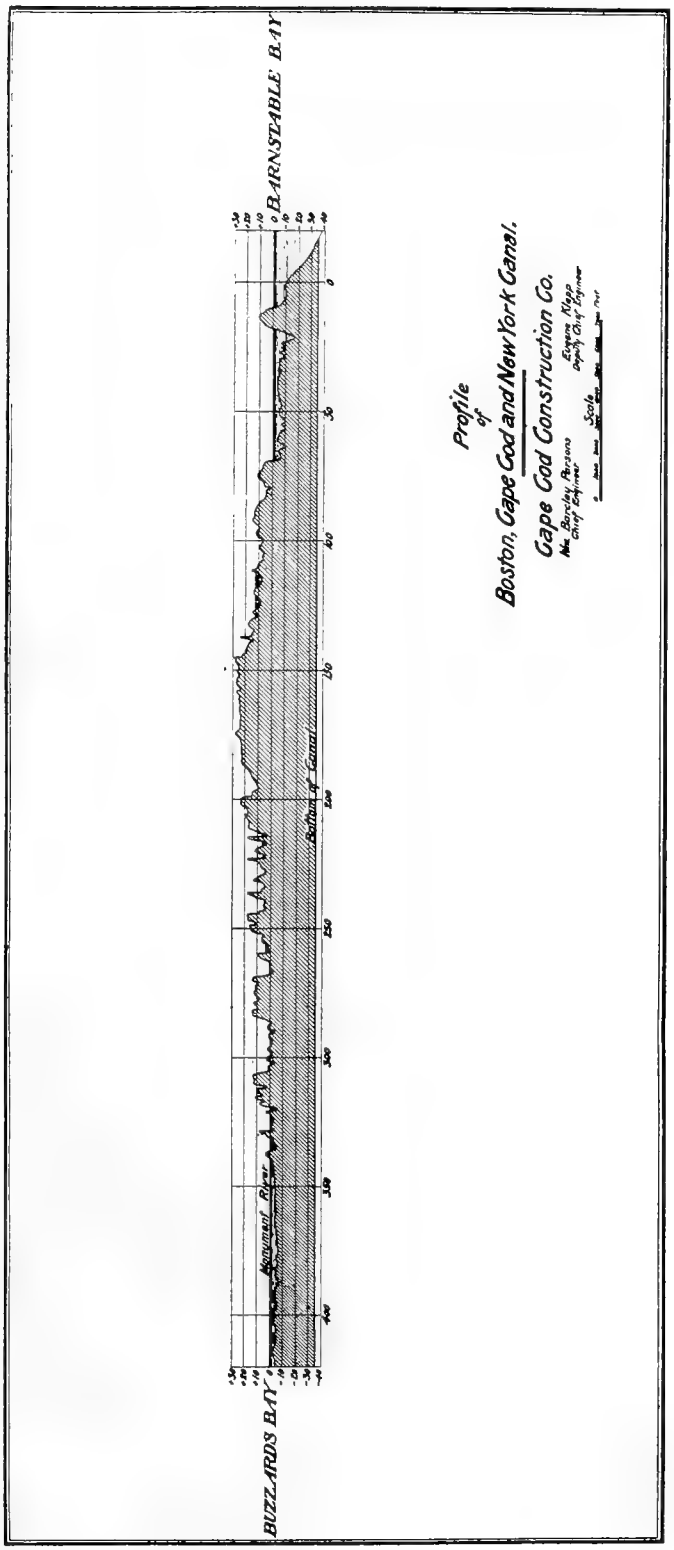


*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President.*



*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President.*

Excavator No. 2. February, 1910.

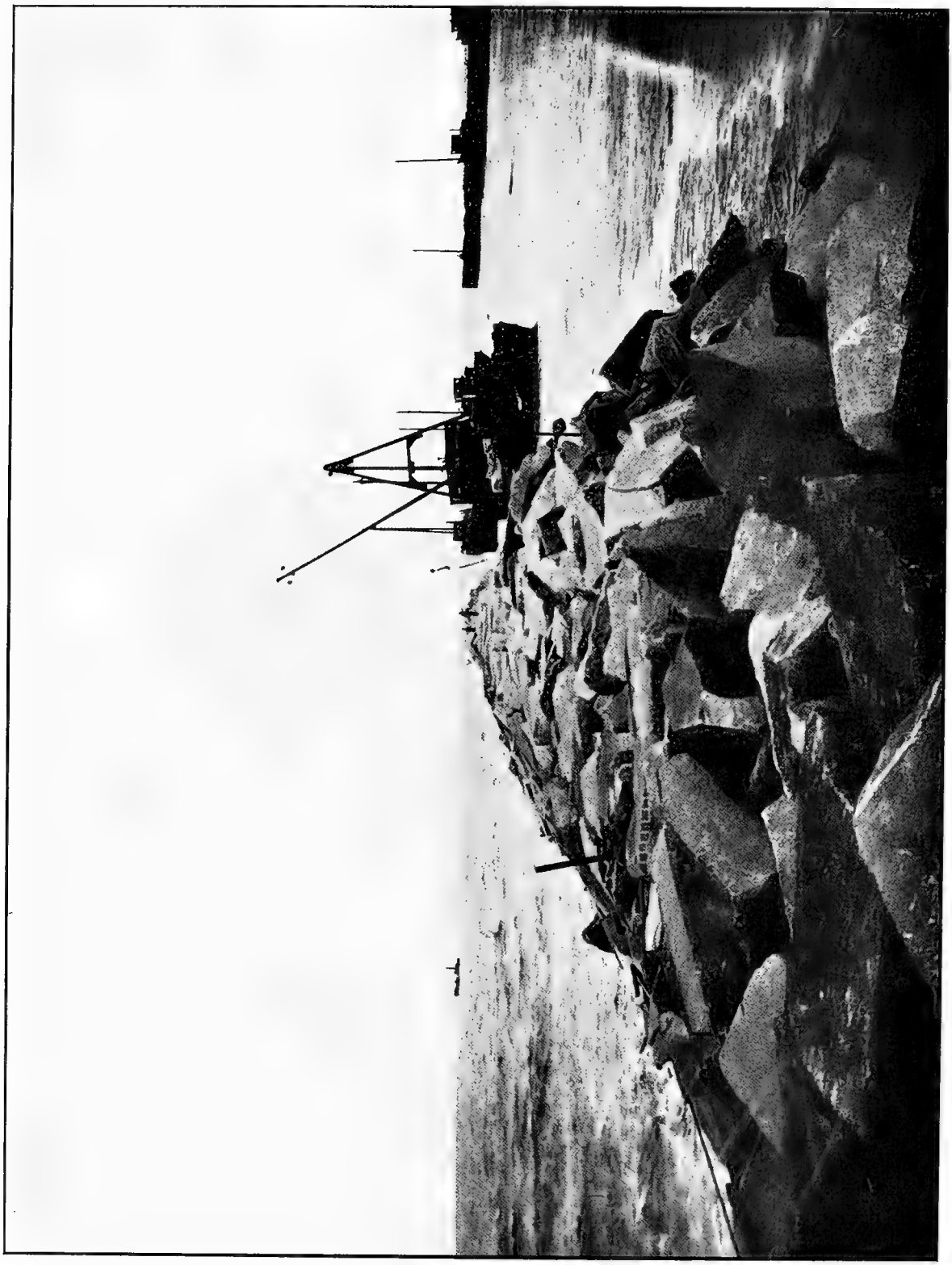
*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President.*

DREDGE NO. 9 IN EASTERN END OF CANAL. MAY, 1910.

*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Cod Canal," by Commodore J. W. Miller, Vice-President.*

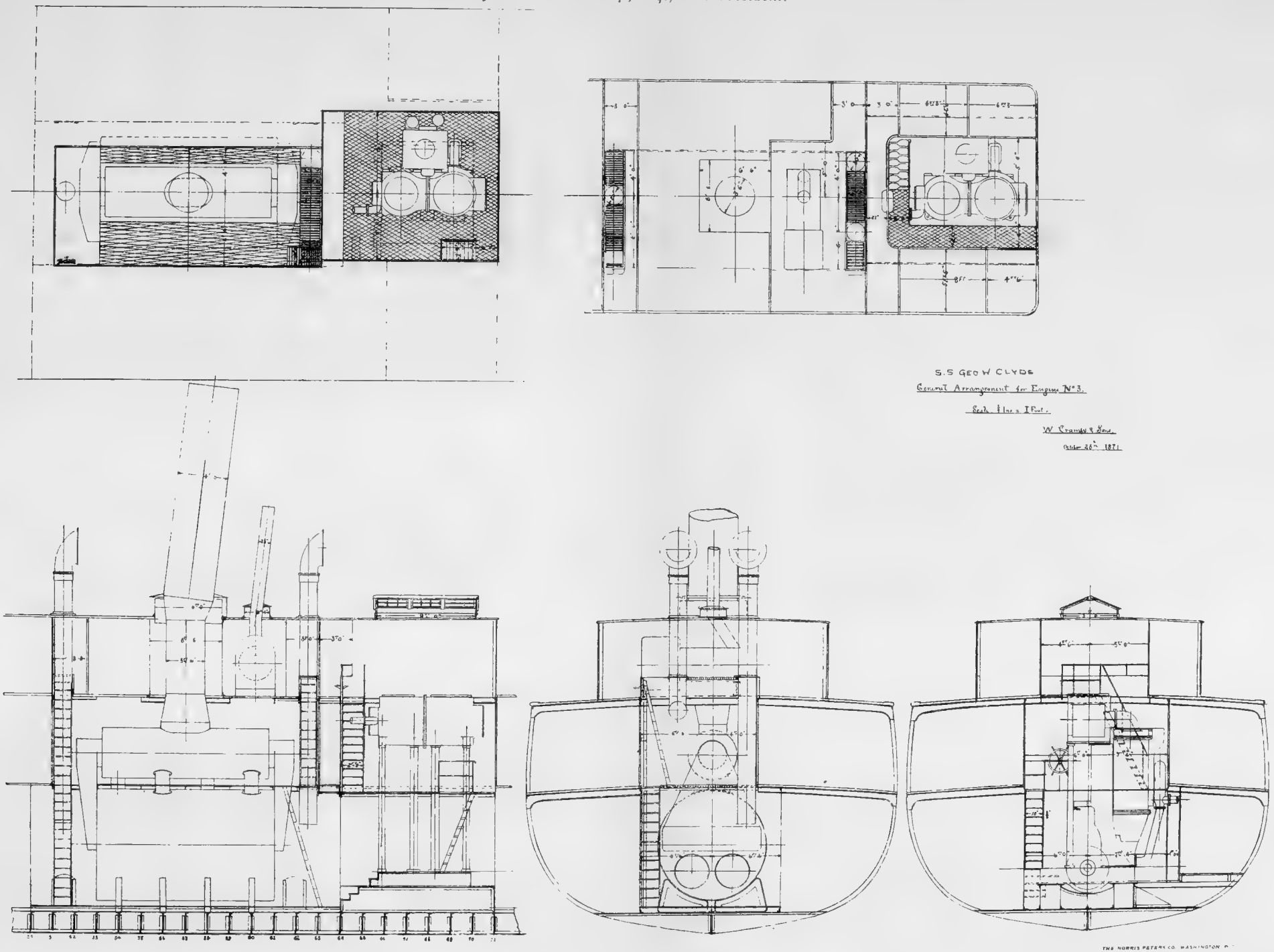
Railroad Bridge, Buzzards Bay. August 12, 1910.

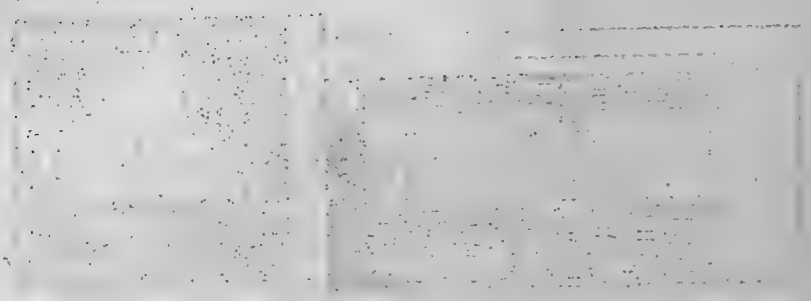
*To illustrate paper on "The History and Economic Value of Canals, with Special Reference to the Cape Code Canal," by Commodore J. W. Miller, Vice-President.*



BREAKWATER, BARNSTABLE BAY. SEPTEMBER, 1910.

*To illustrate paper on "Evolution of Screw Propulsion in the United States," by Charles H. Cramp, Esq., Vice-President.*





*To illustrate paper on "Evolution of Screw Propulsion in the United States," by Charles H. Cramp, Esq., Vice-President.*

2 . Boilers . {1 . Right hand / 1 . Left}

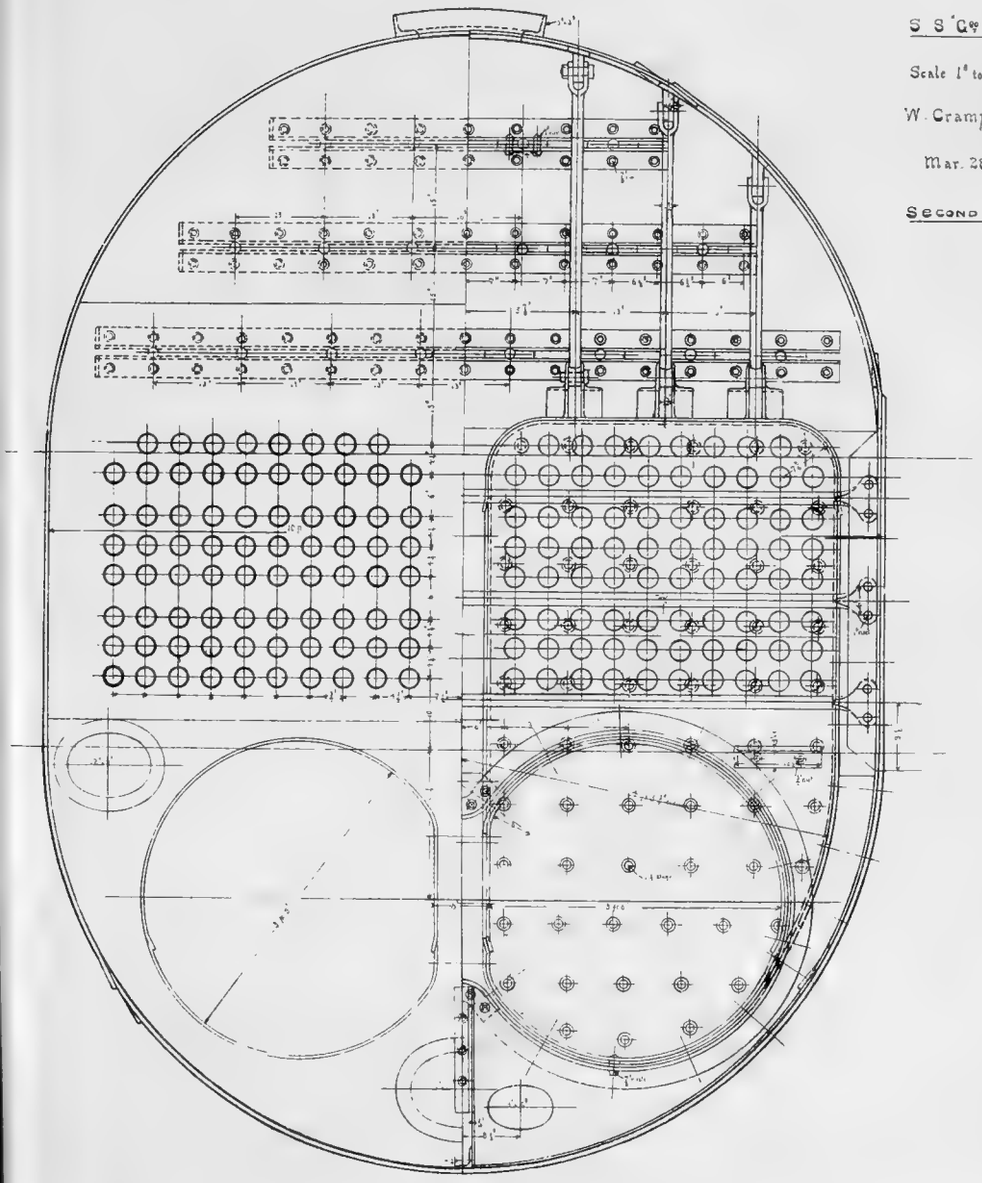
S. S. "Geo W. Clyde".

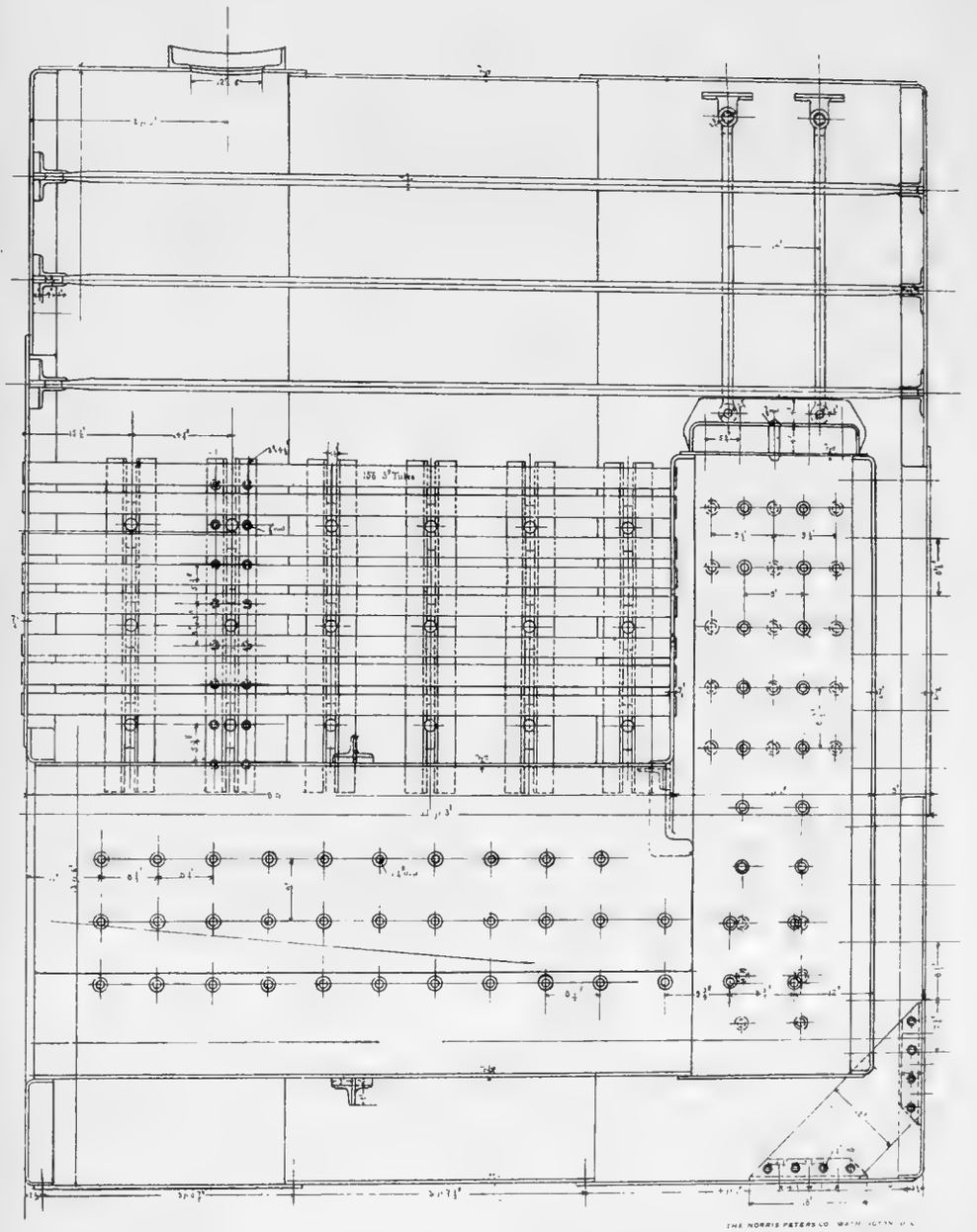
Scale 1" to the foot

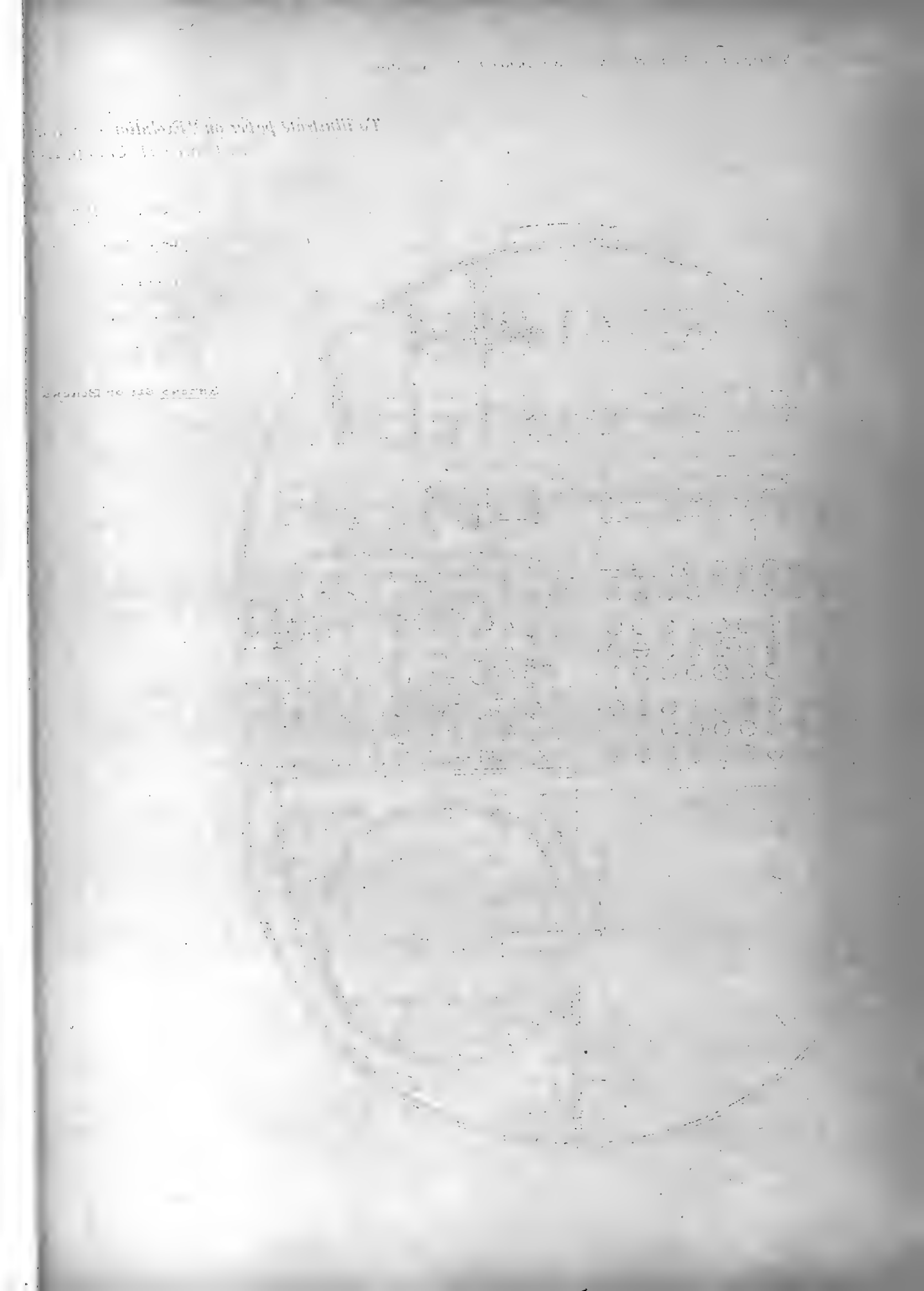
W. Cramp & Sons .

Mar. 28th 1876

SECOND SET OF BOILERS



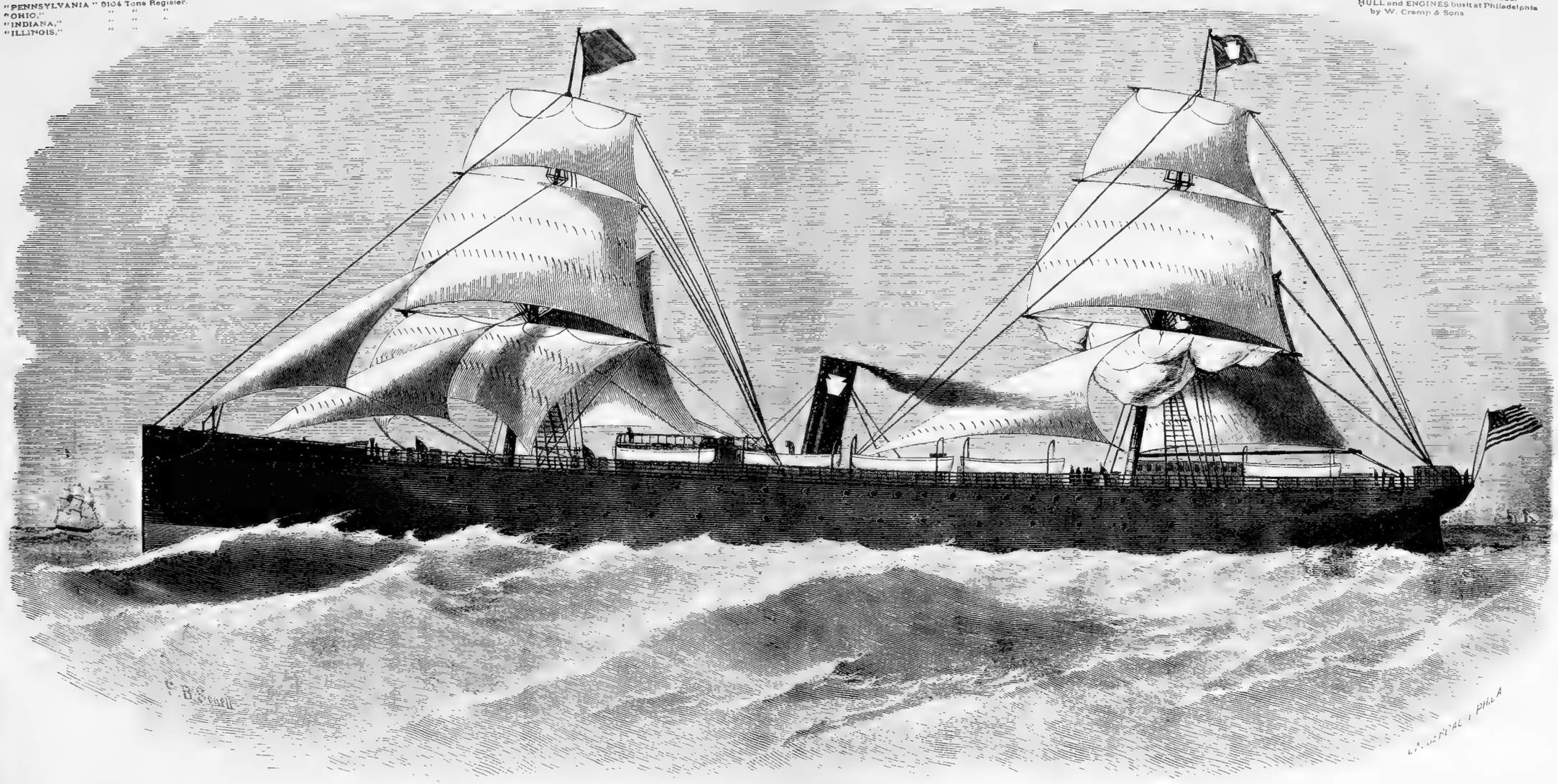




*To illustrate paper on "Evolution of Screw Propulsion in the United States," by Charles H. Cramp, Esq., Vice-President.*

"PENNSYLVANIA" 8104 Tons Register.
"OHIO," " " "
"INDIANA," " " "
"ILLINOIS," " " "

COMPOUND ENGINES
CYLINDERS, 87 and 90 Inches diameter
INDICATED HORSE-POWER, 1800.
HULL and ENGINES built at Philadelphia by W. Cramp & Sons



# AMERICAN STEAMSHIP COMPANY.

PHILADELPHIA AND LIVERPOOL LINE.

THE NORRIS PETERS CO., WASHINGTON, D. C.

*To illustrate paper on "Evolution of Screw Propulsion in the United States,' by Charles H. Cramp, Esq., Vice-President.*

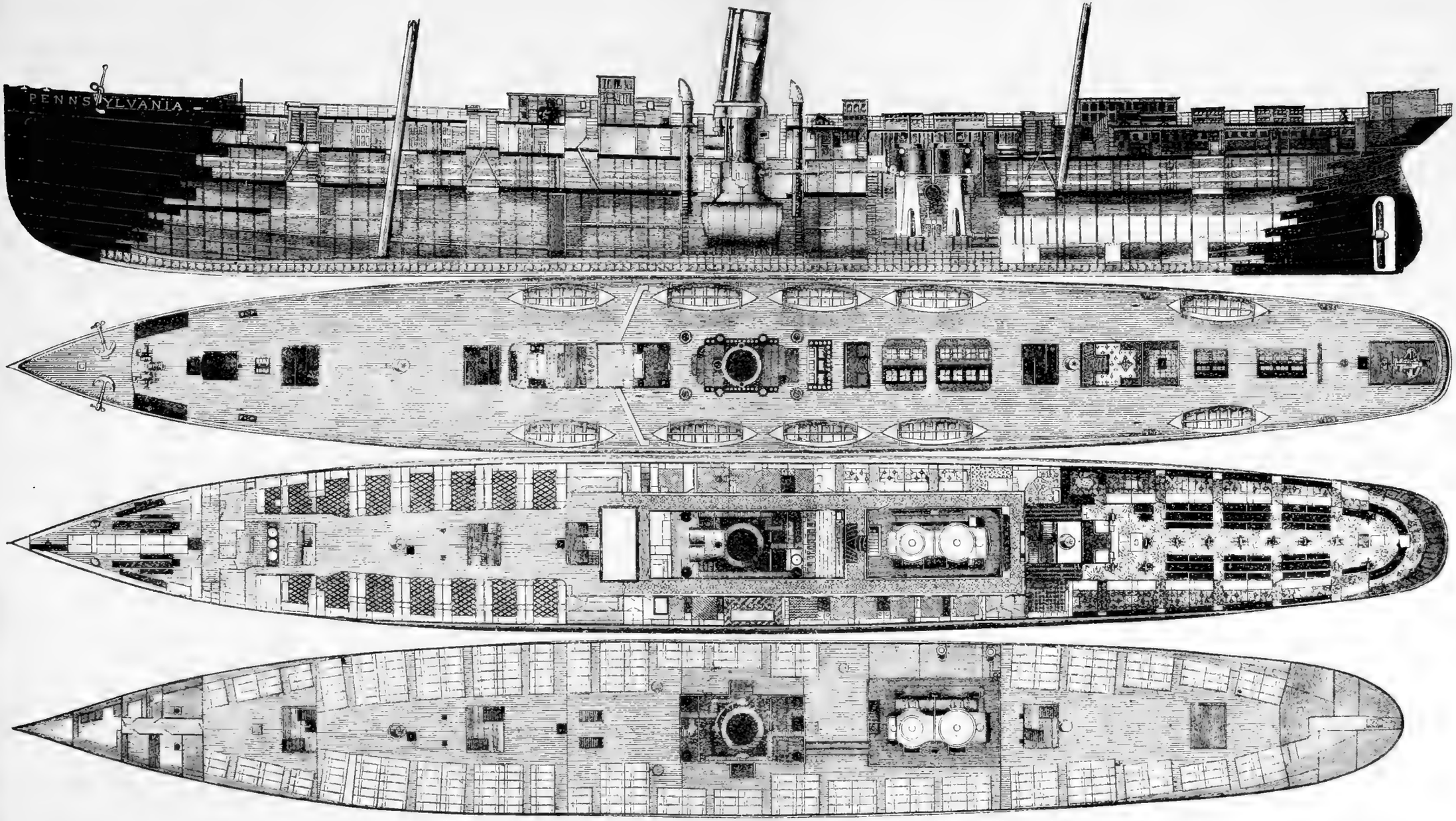
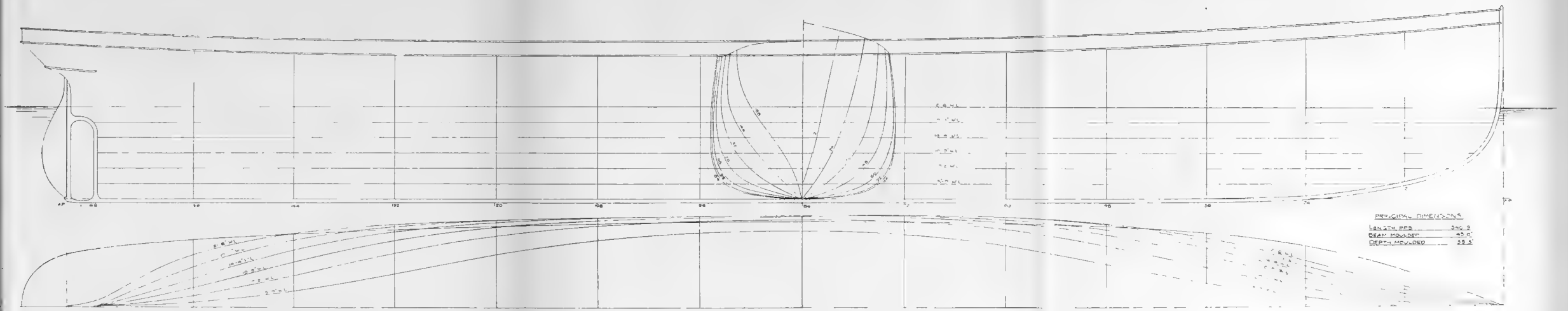


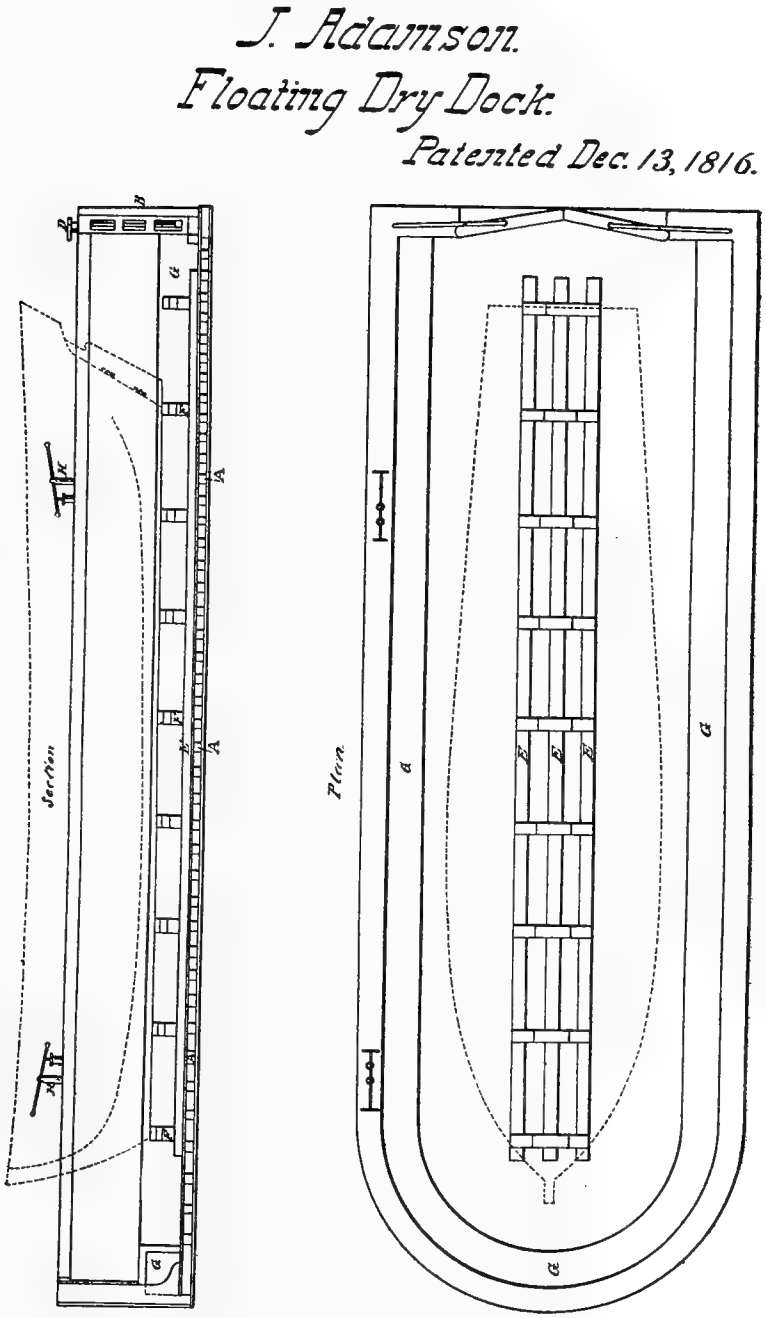

Fig. 66.—Interior arrangement and plans of the decks of the steamship Pennsylvania, of the American line from Philadelphia to Liverpool.

THE NORRIS PETERS CO., WASHINGTON, D. C.

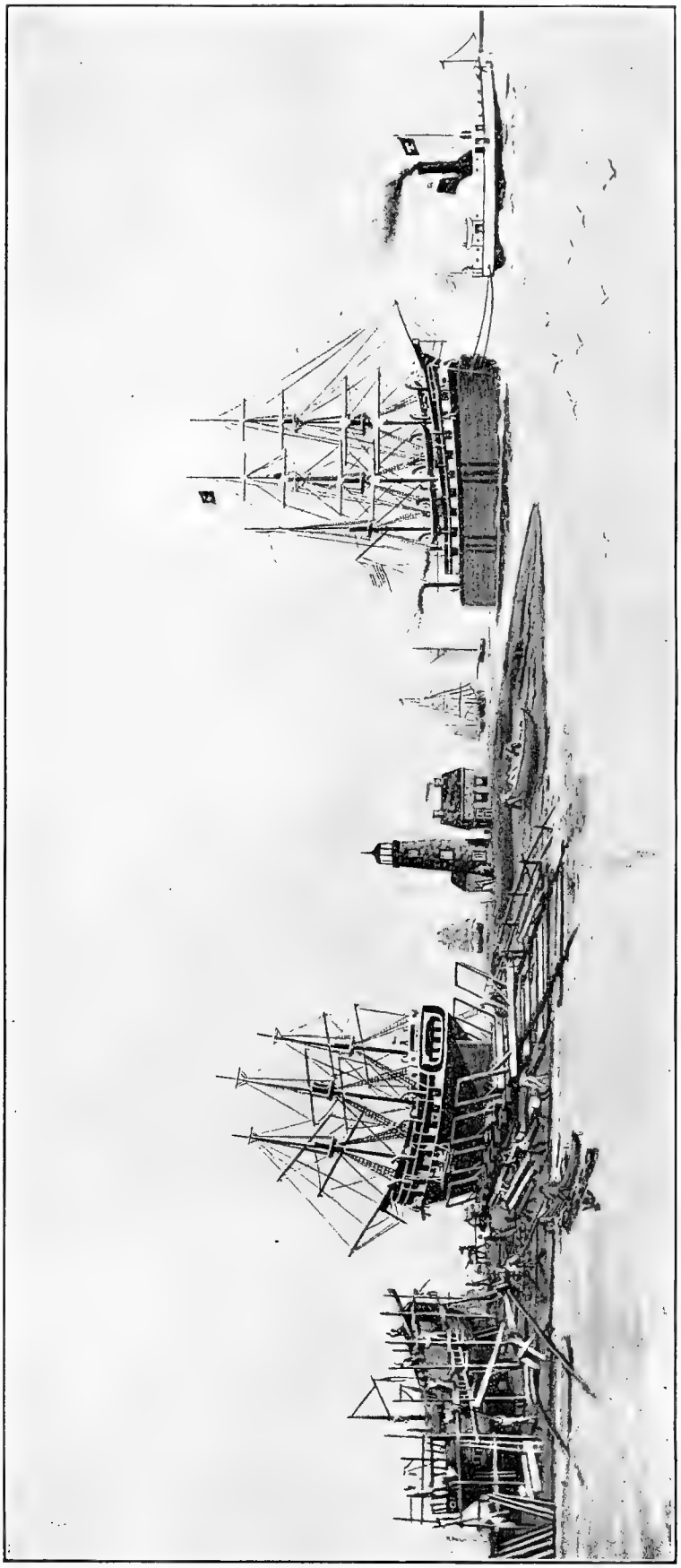
*To illustrate paper on "Evolution of Screw Propulsion in the United States," by Charles H. Cramp, Esq., Vice-President.*



*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*

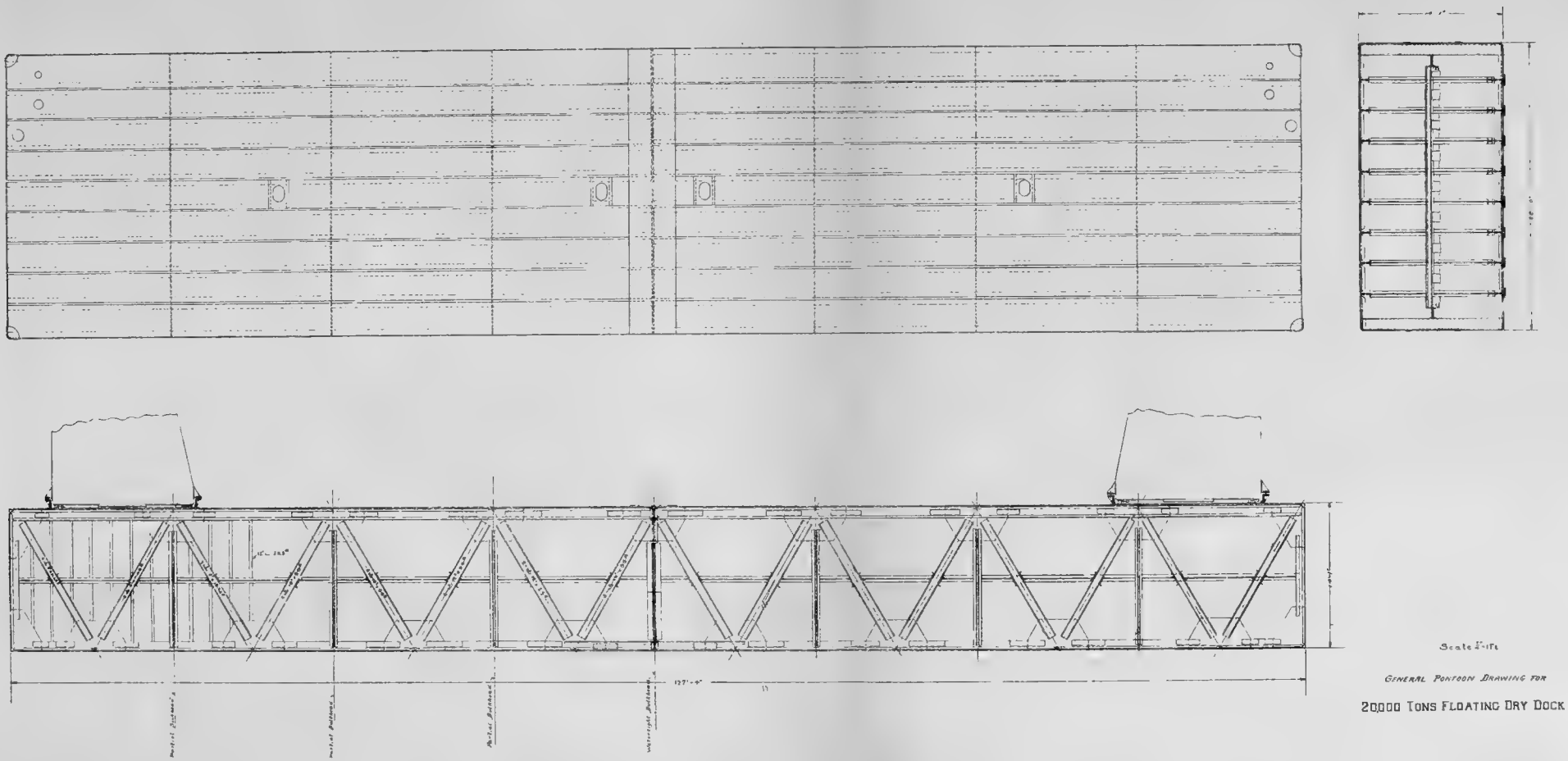


*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



A View of Brant Point and Entrance to Harbor at Nantucket, Mass., from 1820 to 1842.

*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*

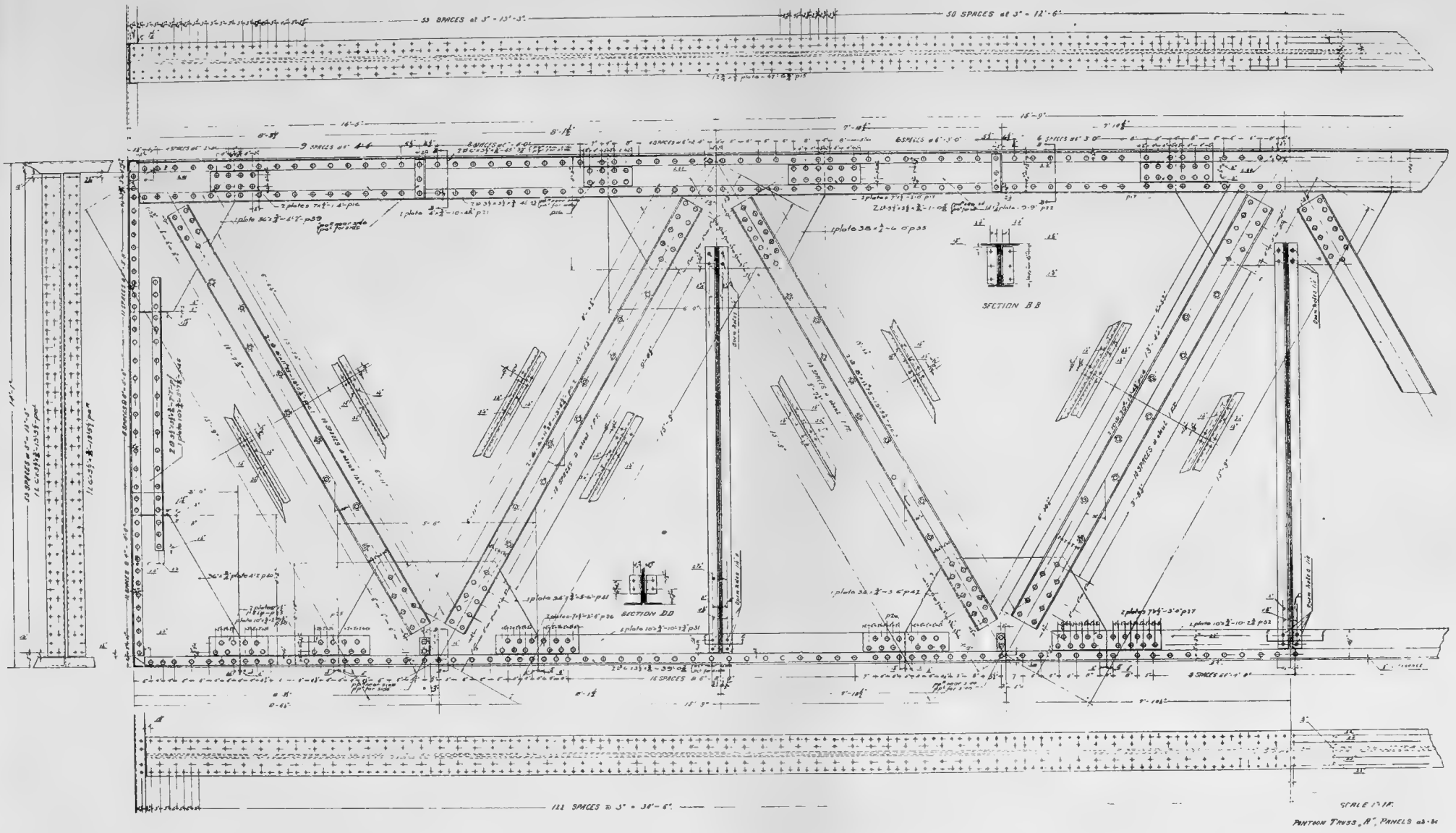


Scale 1/16 ft.

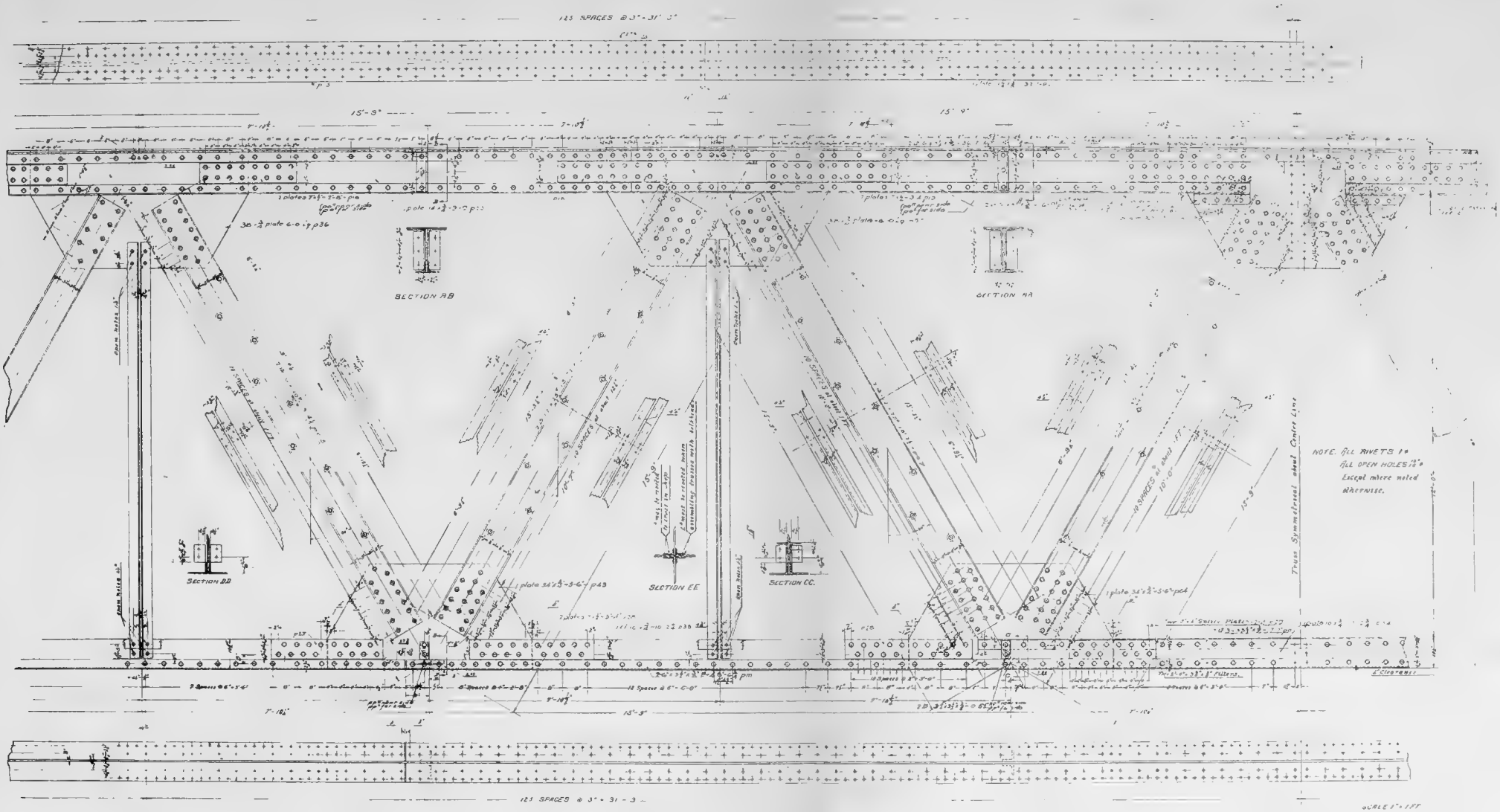
GENERAL PONTOON DRAWING FOR

20000 TONS FLOATING DRY DOCK

*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*

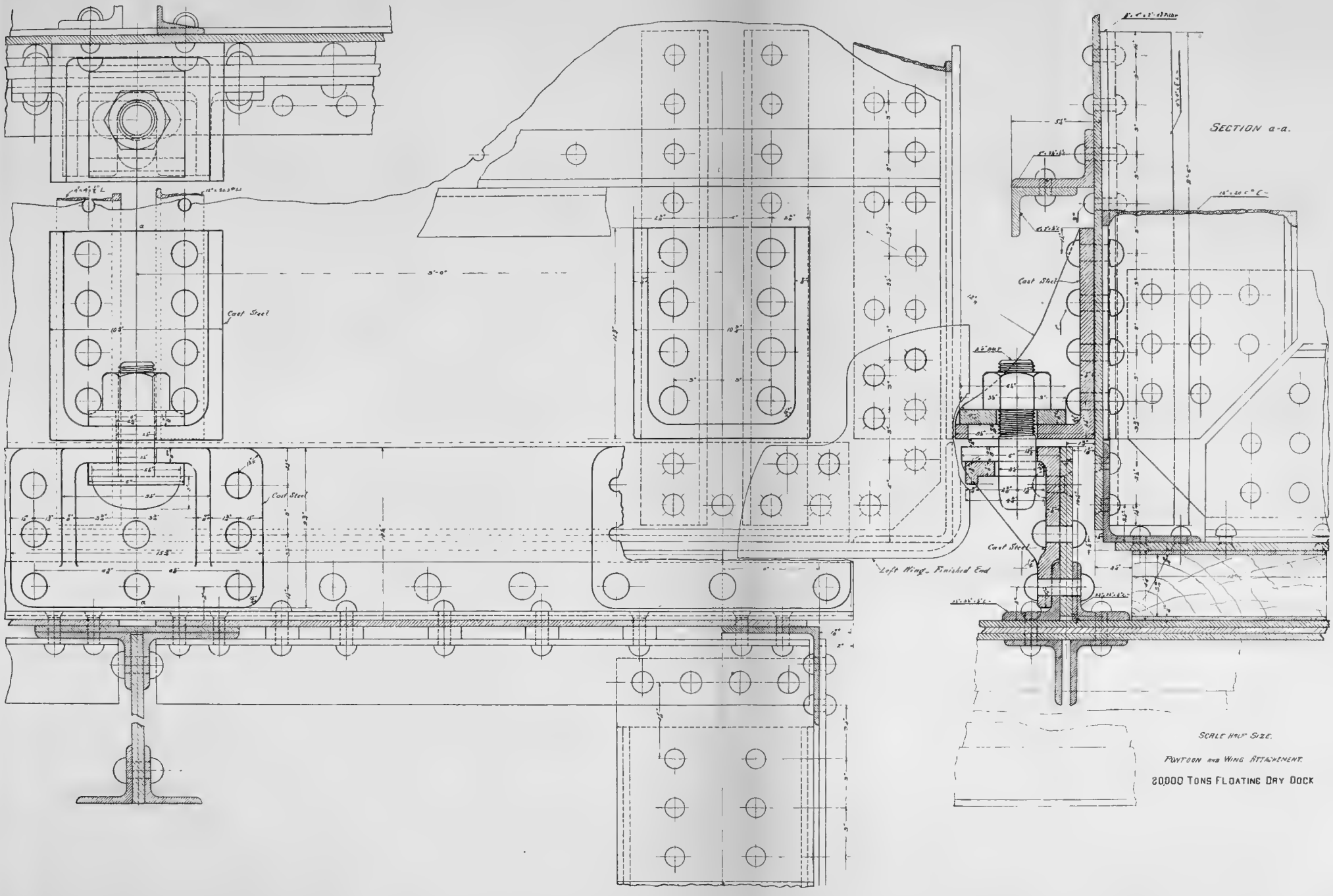


*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*




20000 TONS FLOATING DRY DOCK

*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



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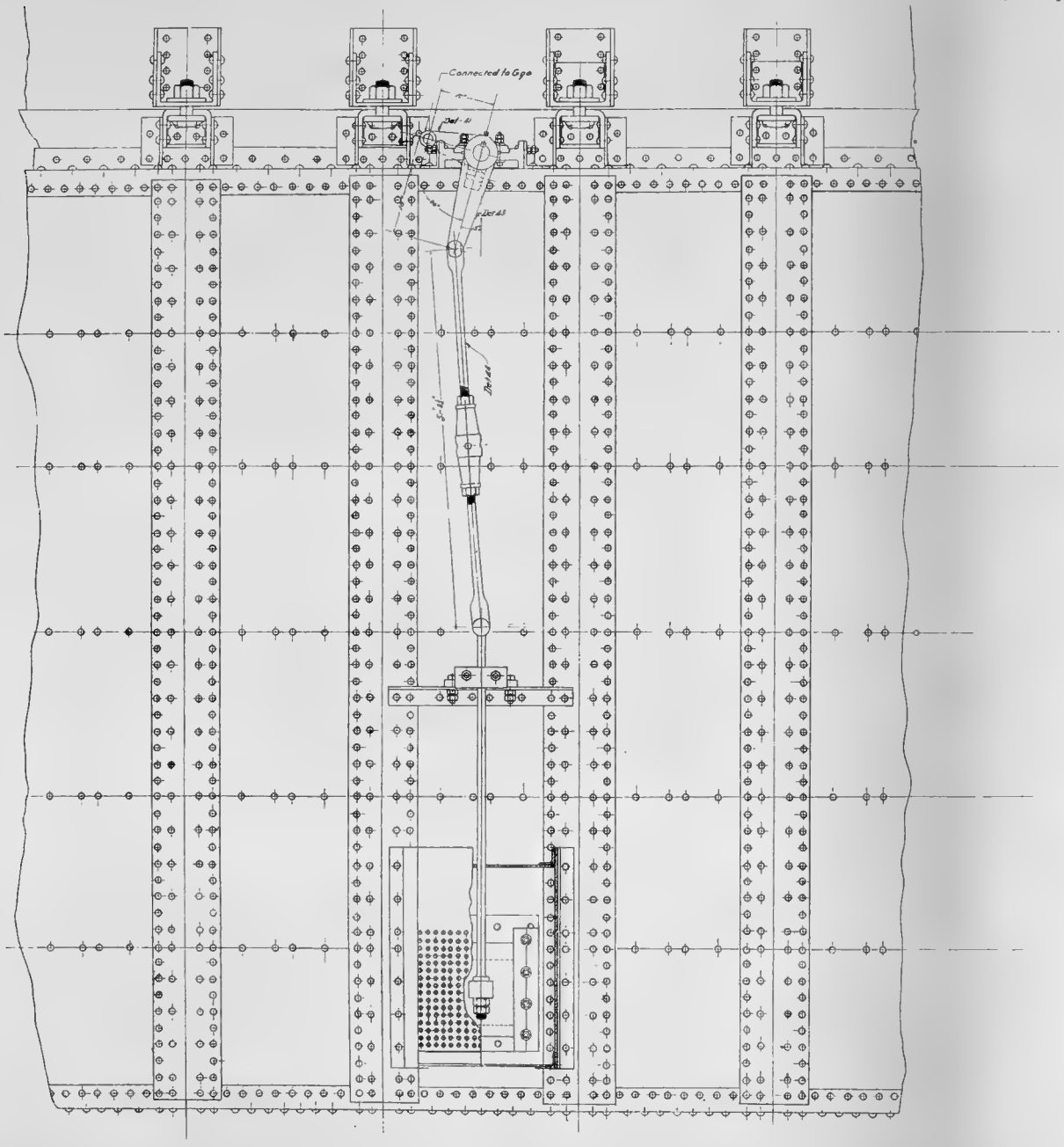
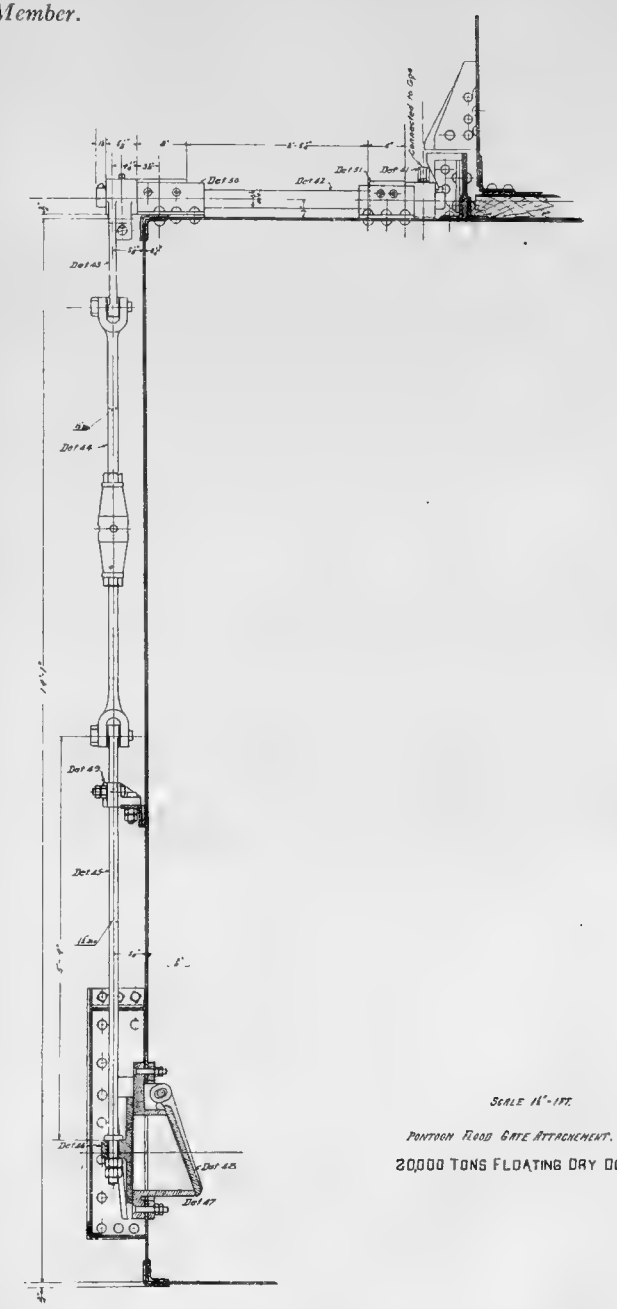


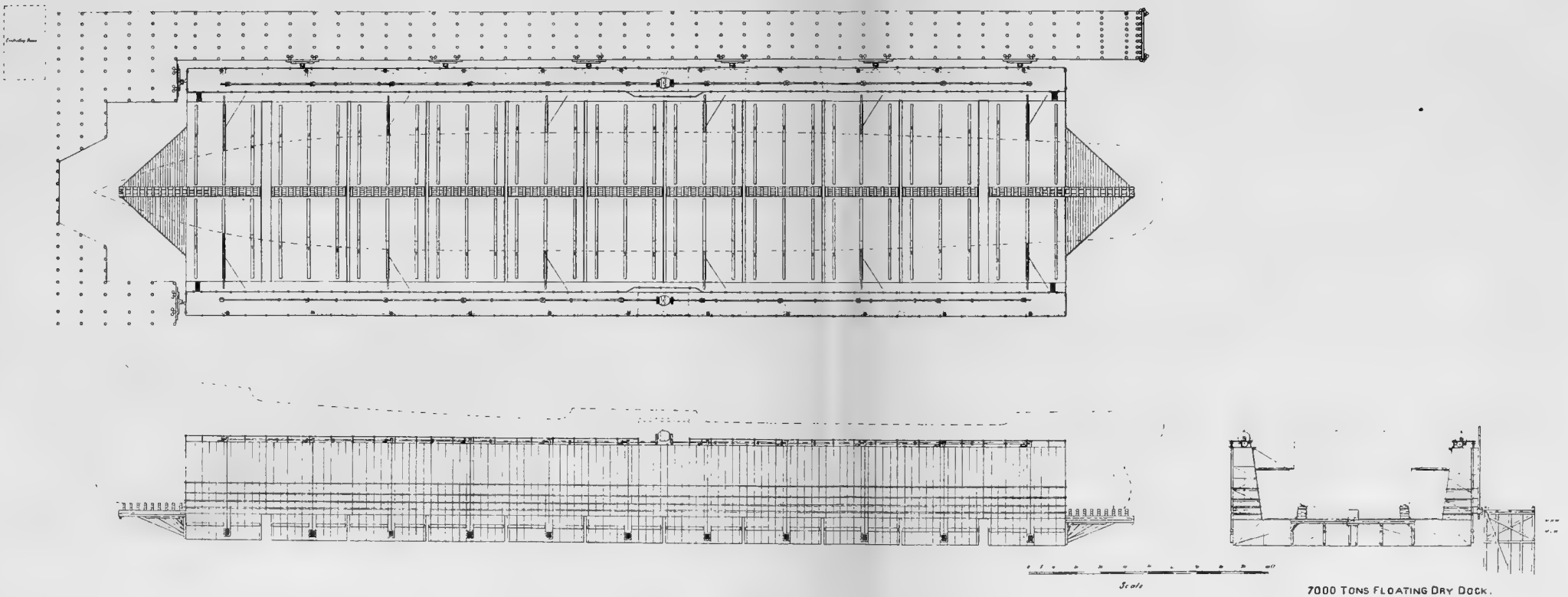




SCALE 1½"-1FT.

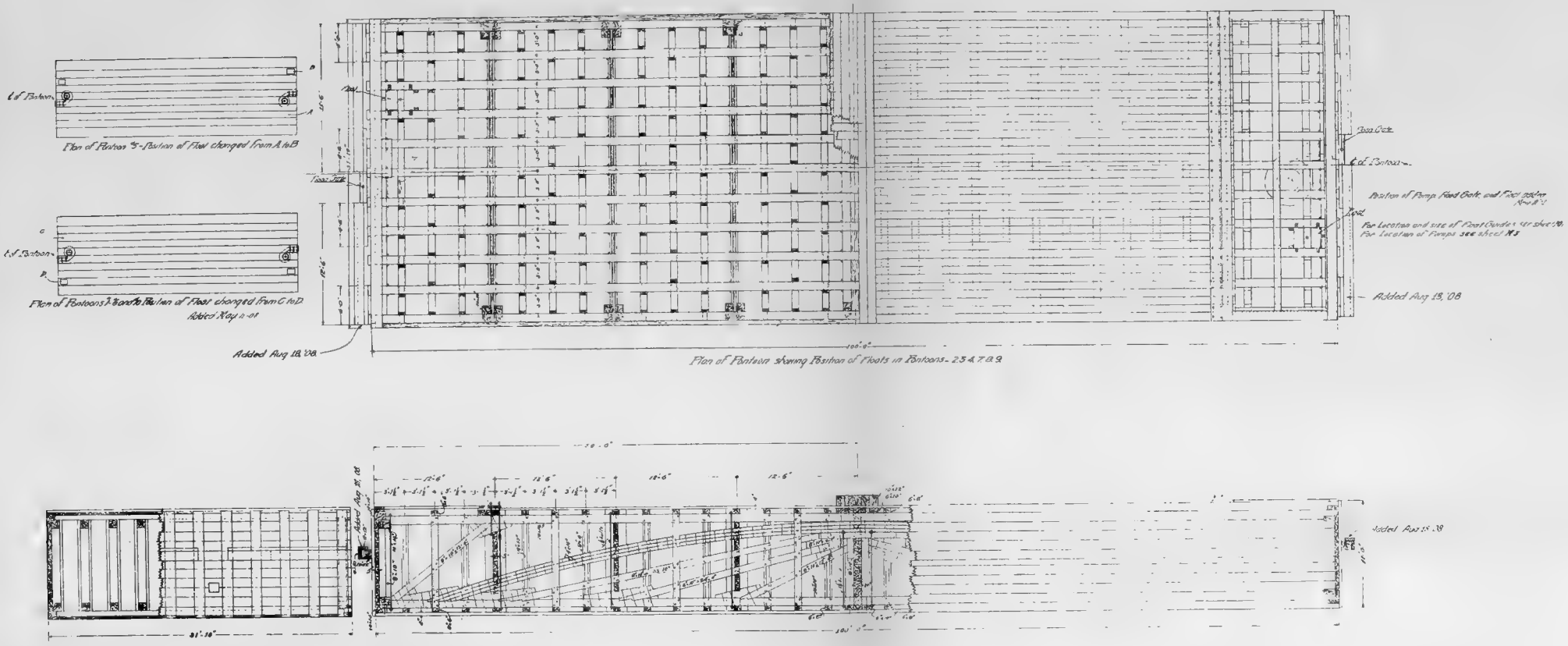
PONTOON FLOOD GATE ATTACHMENT.

20,000 TONS FLOATING DRY DOCK

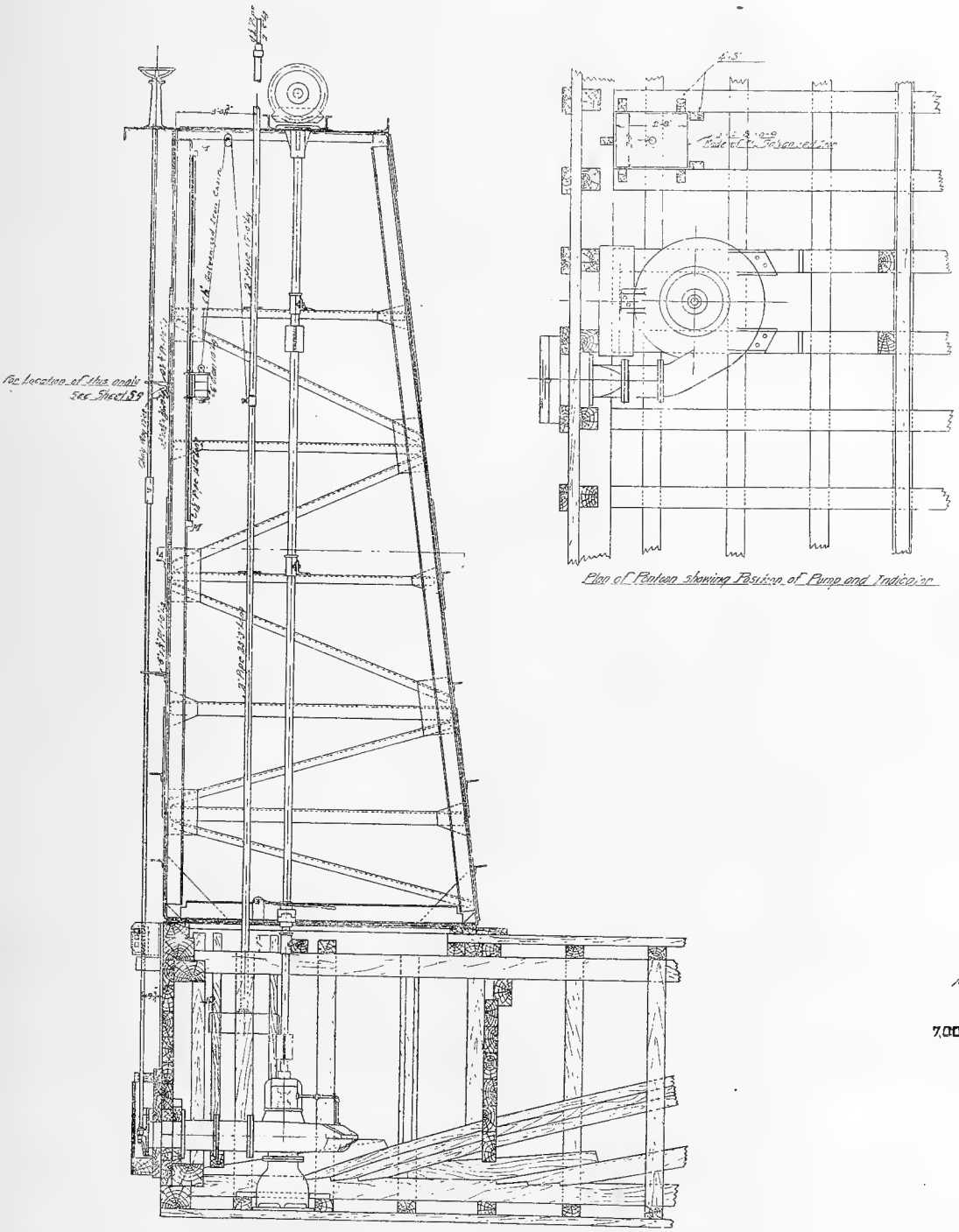
*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



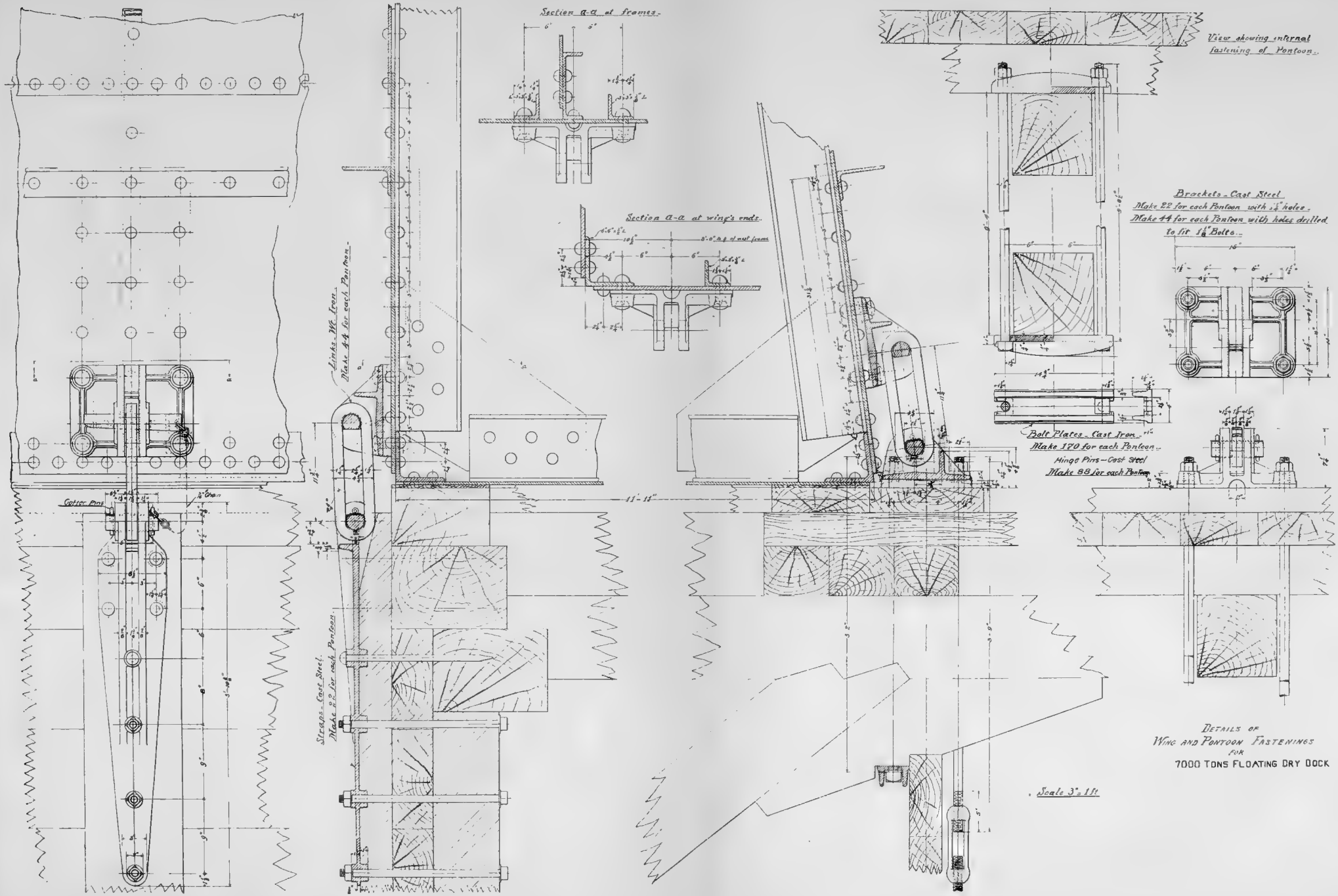
*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



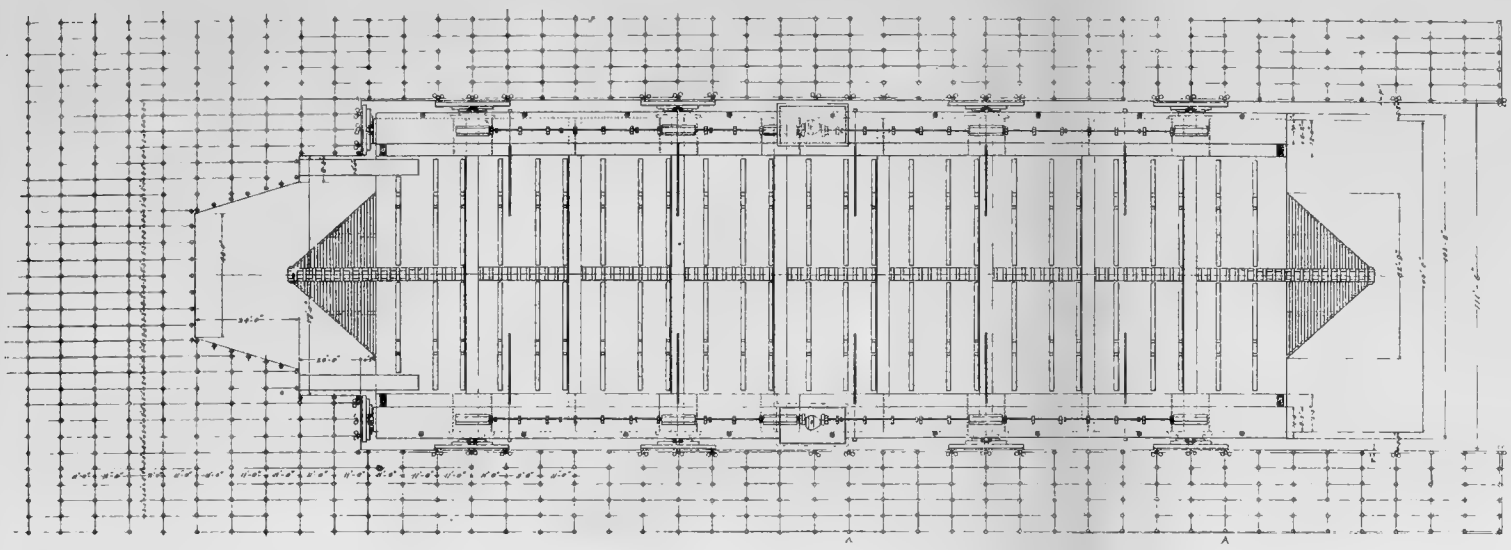

Arrangement of Pumps & Indicators
Scales ½"=1 Ft. and 3"=1 Ft. and ½"=1 Ft.

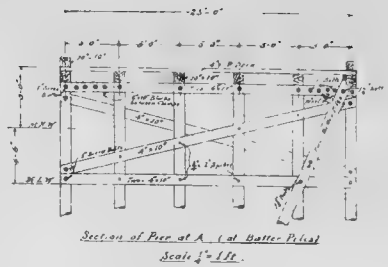
7,000 TONS FLOATING DRY DOCK

*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*

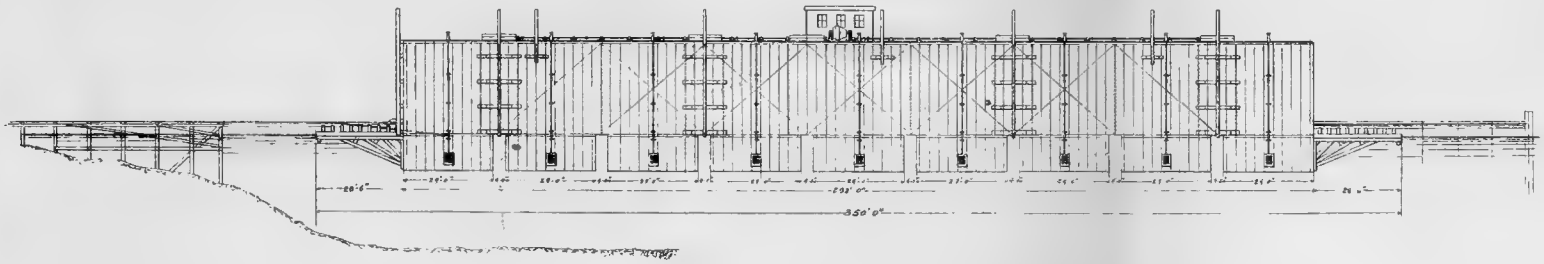


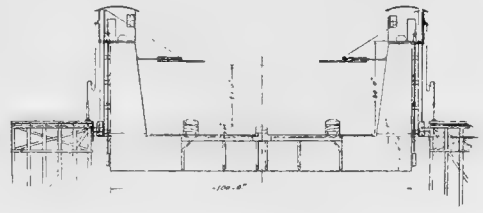
*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*





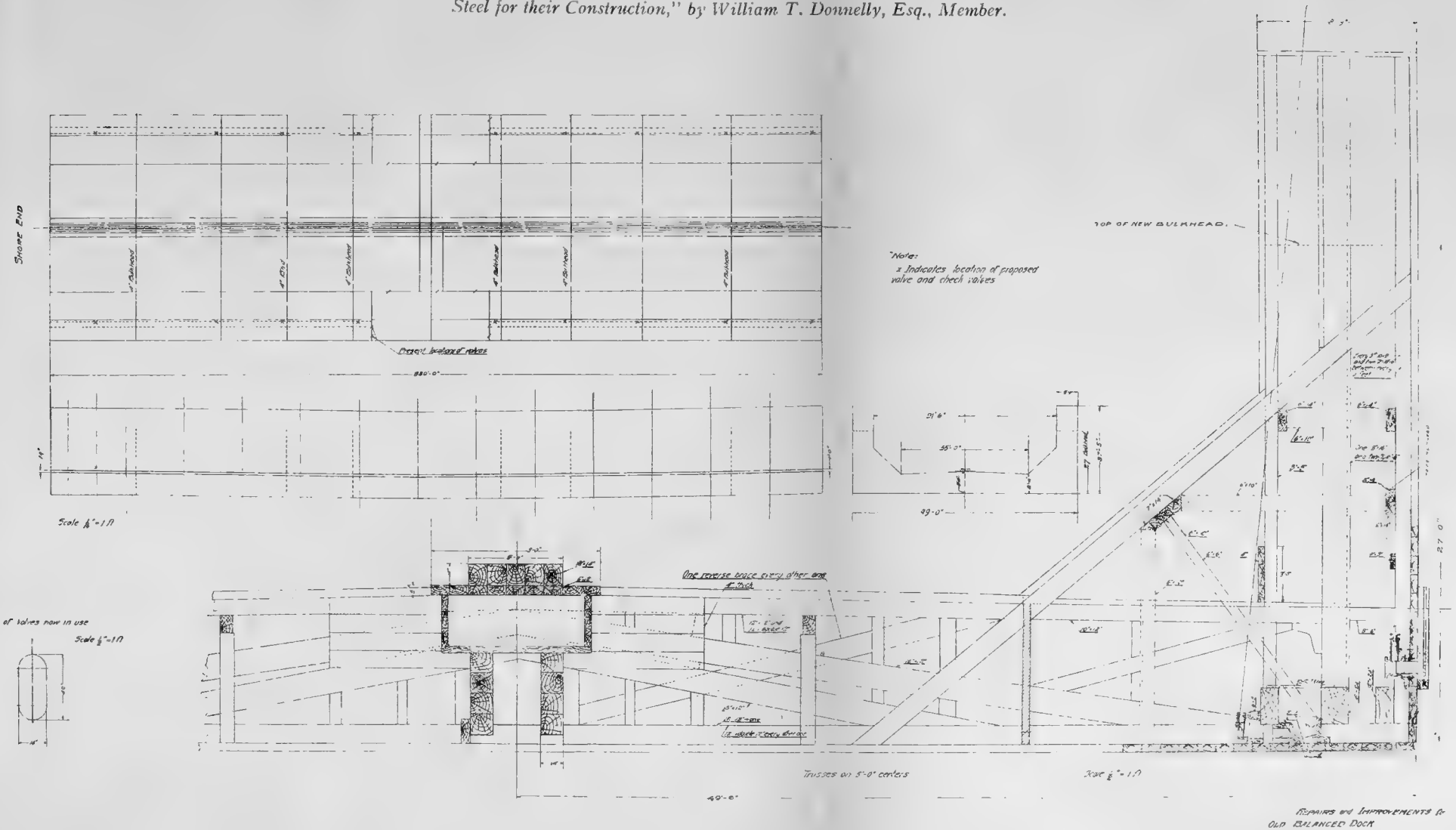
Section of Pier at A (at Batter Piles)
Scale 1/4" = 1 Ft.



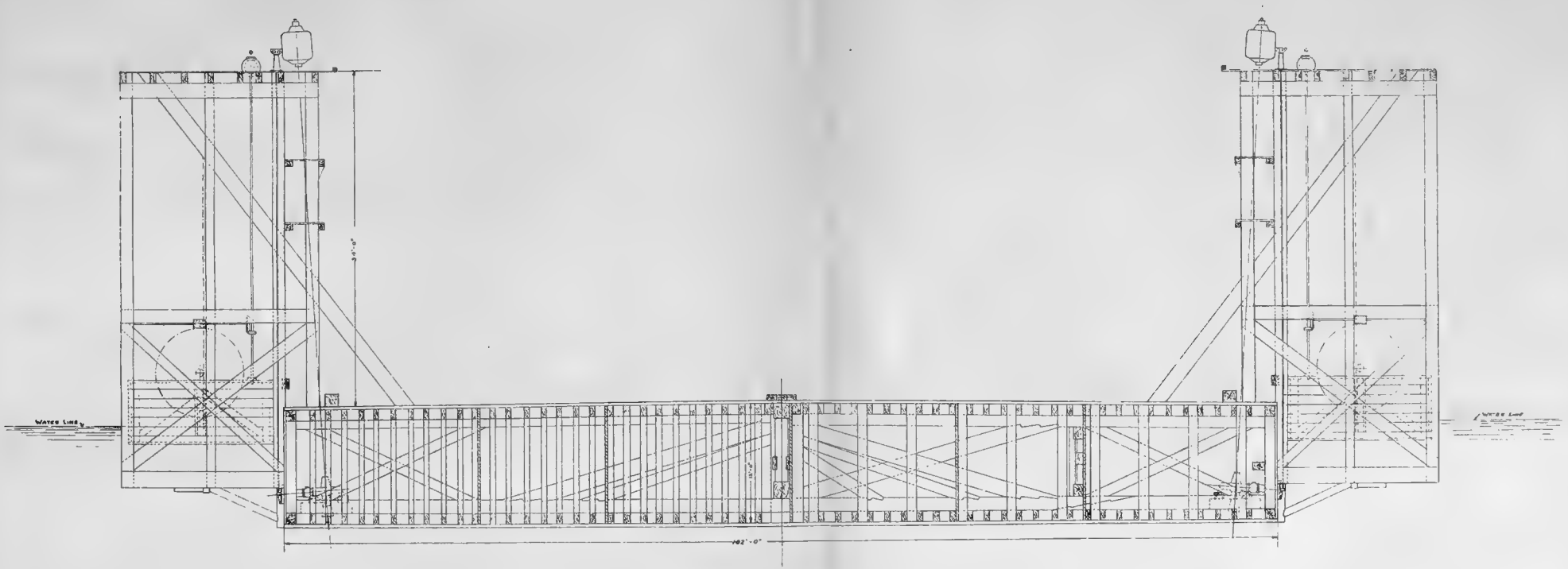


5000 Tons Pontoon
Floating Dry Dock

*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



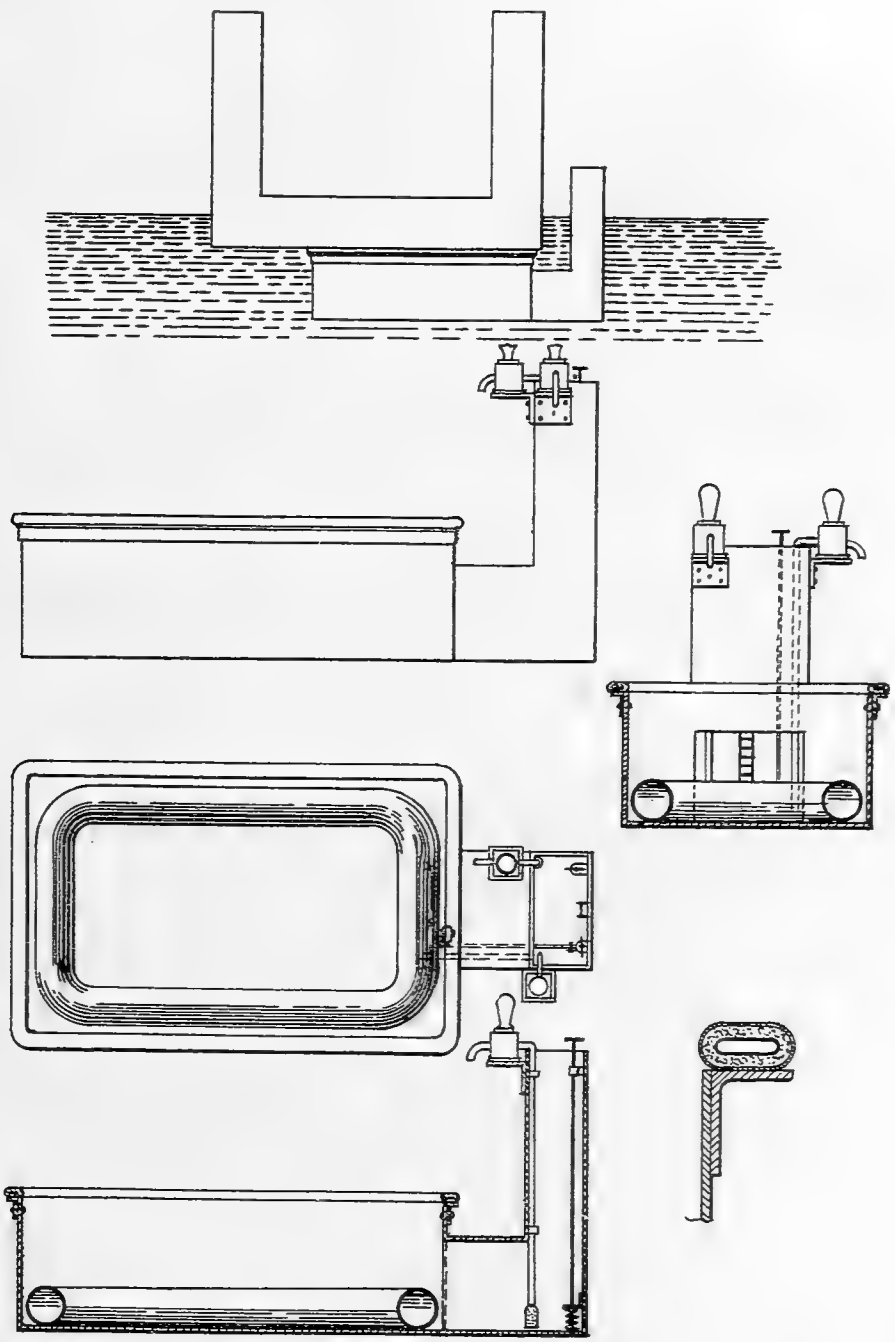
*To illustrate paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



*Dodge Burgess.*

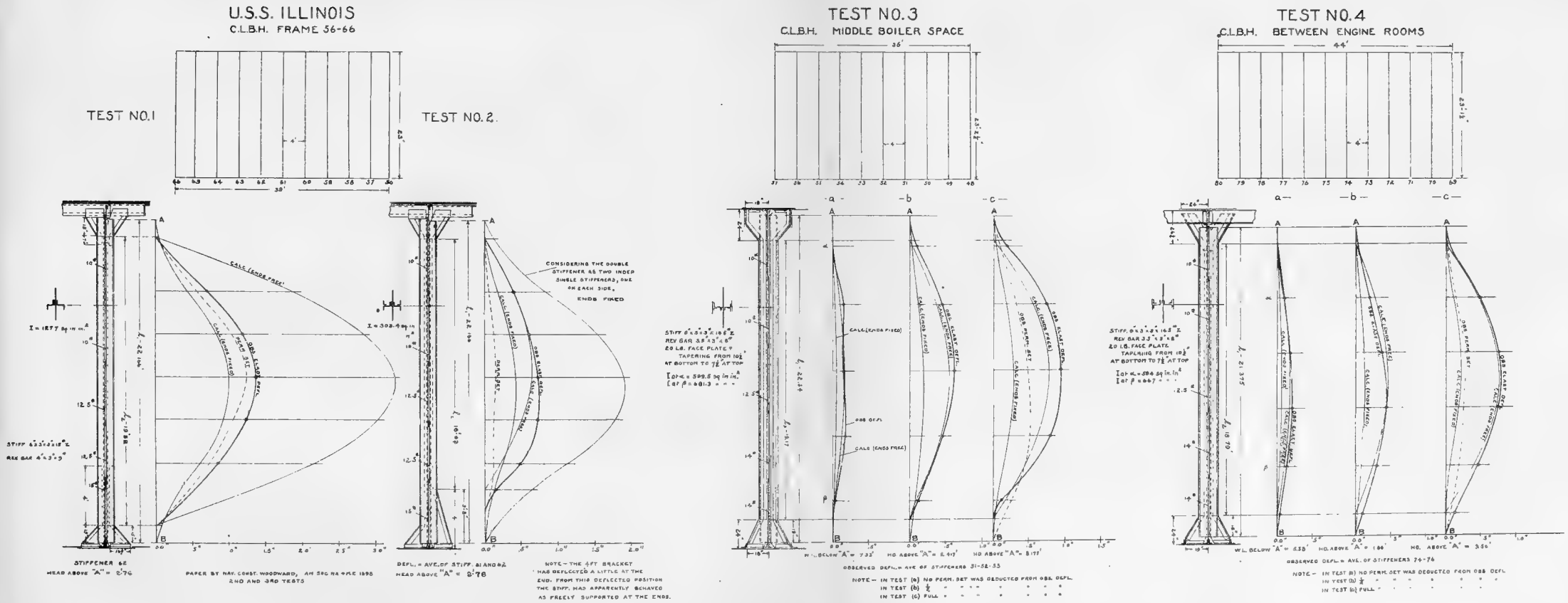
SECTIONAL FLOATING DRY DOCK.

*To illustrate remarks by Civil Engineer A. C. Cunningham, U. S. N., on paper on "Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction," by William T. Donnelly, Esq., Member.*



Construction" by William T. Donnelly, Esq., Member.

*To illustrate paper on "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for their Construction," by Professor William Hovgaard, Member.*

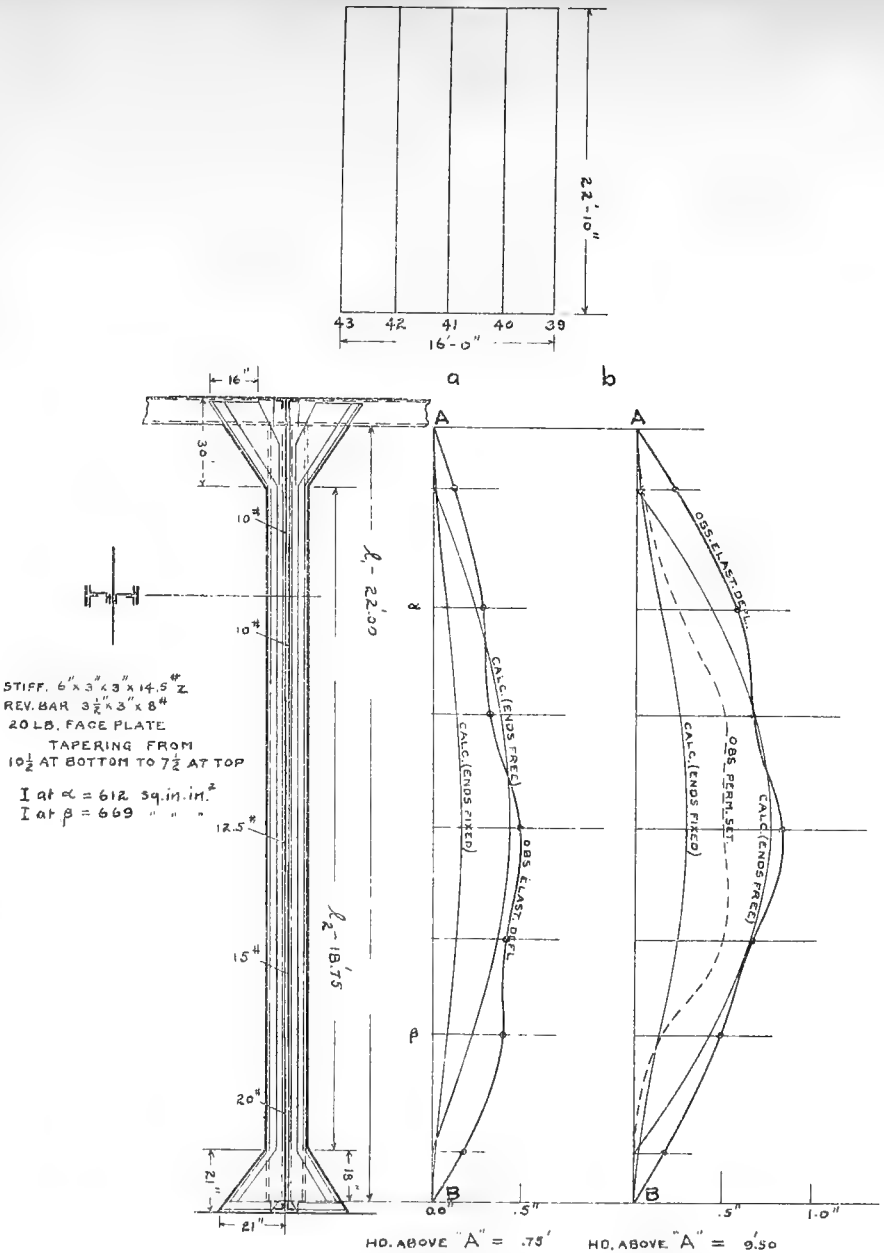


*To illustrate paper on "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for their Construction," by Professor William Hovgaard, Member.*



# TEST NO. 5

C.L.B.H. FRAME 39-43




STIFF. 6"x3"x3"x14.5# Z
REV. BAR 3½"x3"x8#
20 LB. FACE PLATE
TAPERING FROM
10½ AT BOTTOM TO 7½ AT TOP

I at α = 612 sq.in.in.²
I at β = 669 " " "

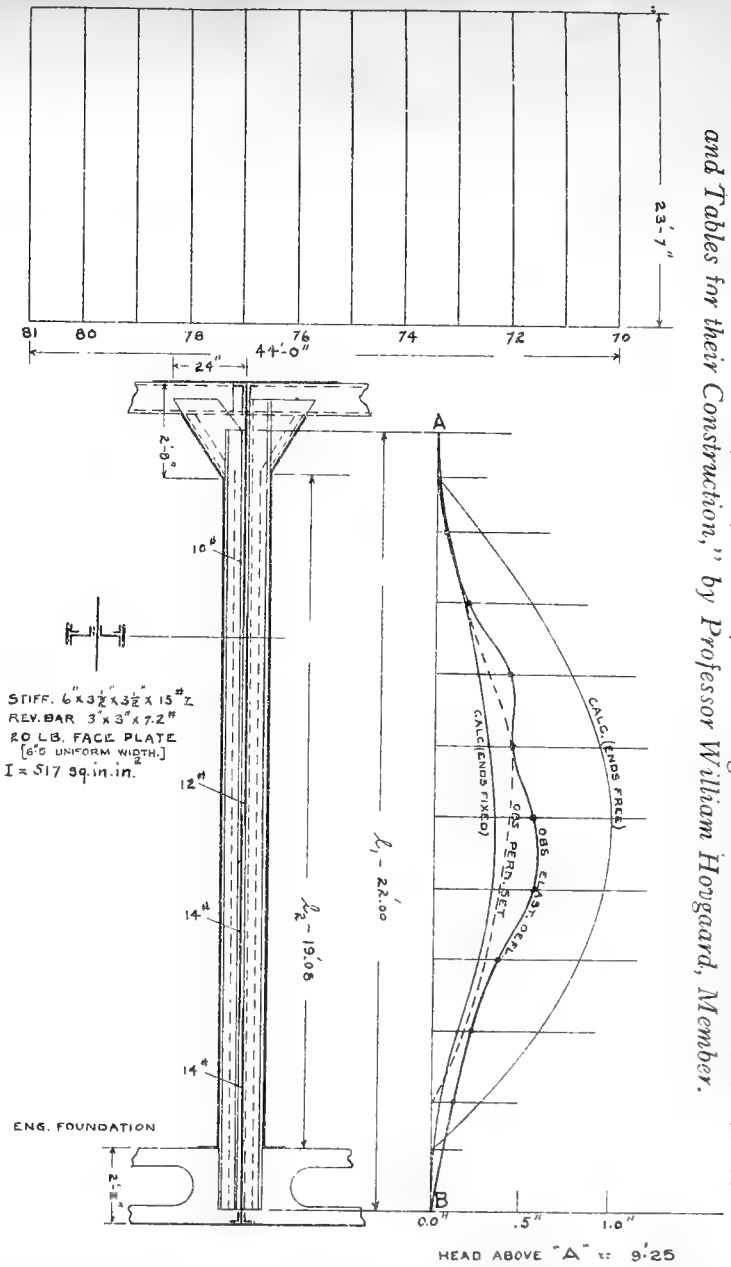
HD. ABOVE "A" = .75' HD. ABOVE "A" = 9.50

OBS. DEFLECTIONS = STIFF. 41

NOTE. IN TEST (a) ¼ PERM. SET WAS DEDUCTED FROM OBS. DEFL.
IN TEST (b) FULL " " " " " " "

# TEST NO. 6

C.L.B.H. BETWEEN ENGINE ROOMS

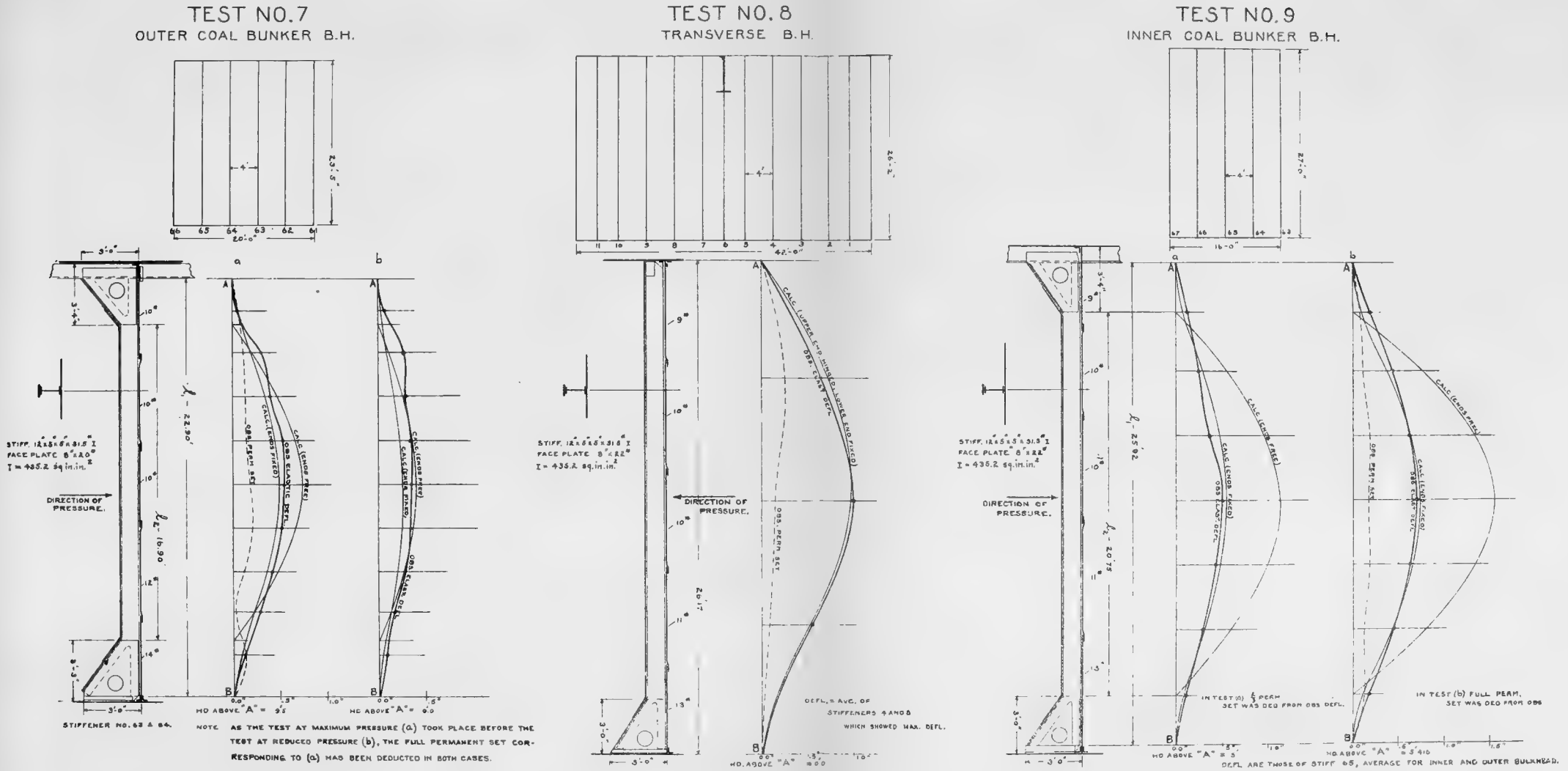



STIFF. 6"x3½"x3½"x15# Z
REV. BAR 3"x3"x7.2#
20 LB. FACE PLATE
[6'-6 UNIFORM WIDTH.]
I = 517 sq.in.in.

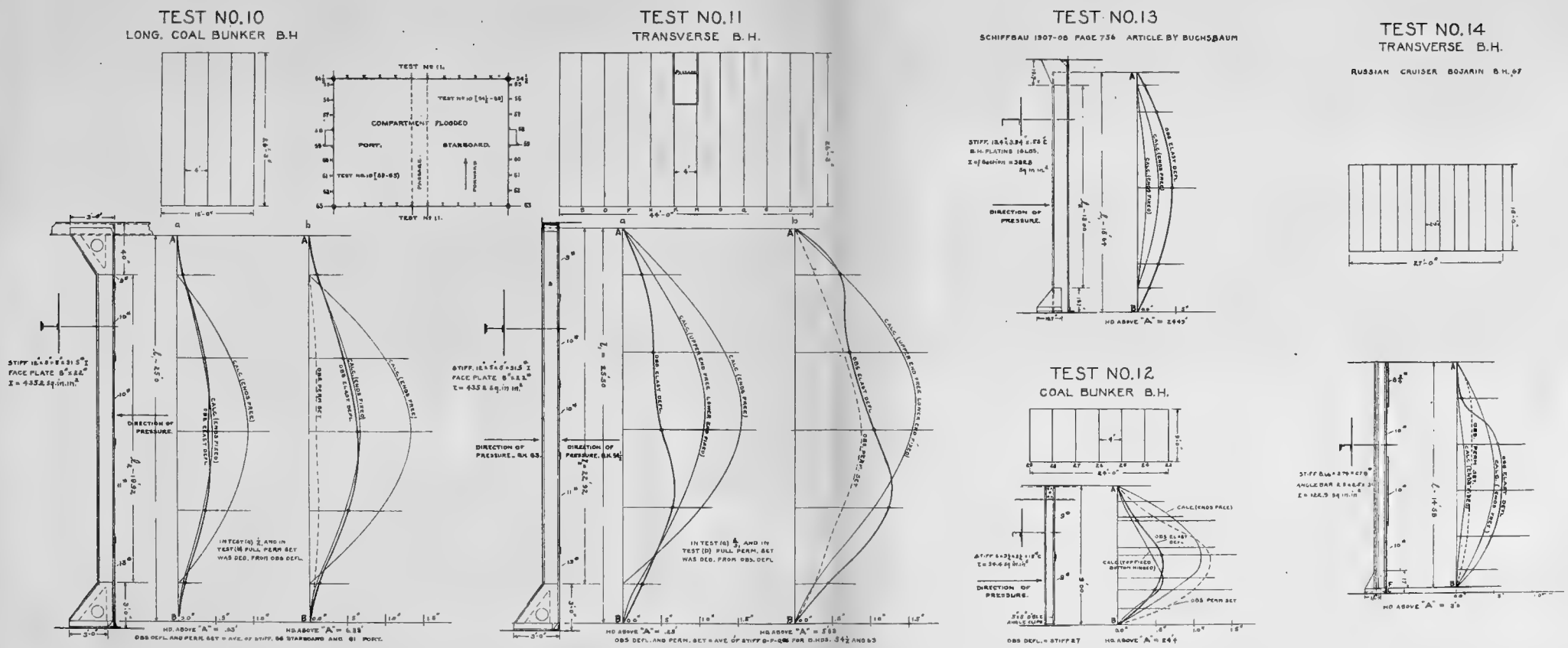
HEAD ABOVE "A" = 9.25

OBS. DEFLECTIONS = AVE. OF STIFFENERS 74 AND 76

*To illustrate paper on "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for their Construction," by Professor William Hovgaard, Member.*

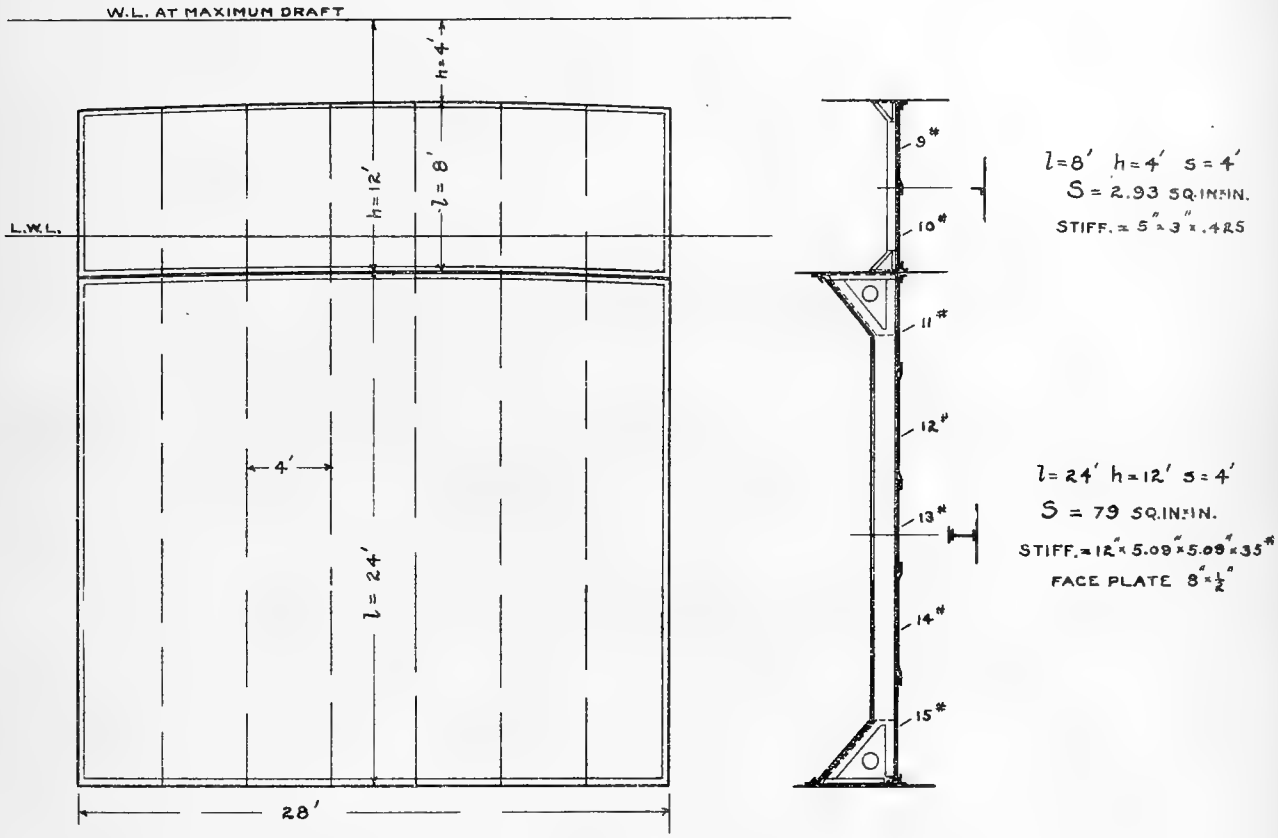


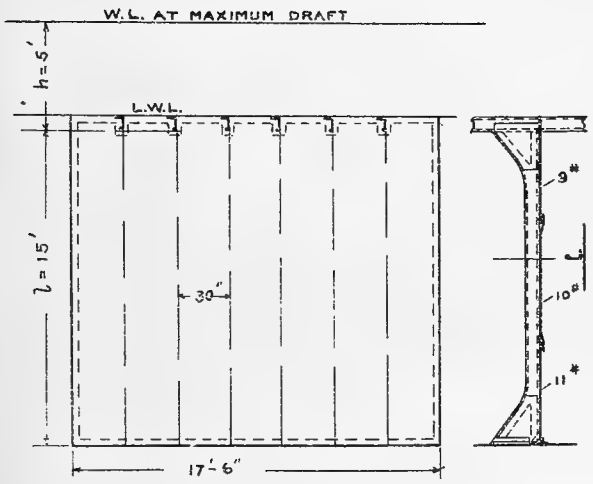
*To illustrate paper on "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for their Construction," by Professor William Hovgaard, Member.*



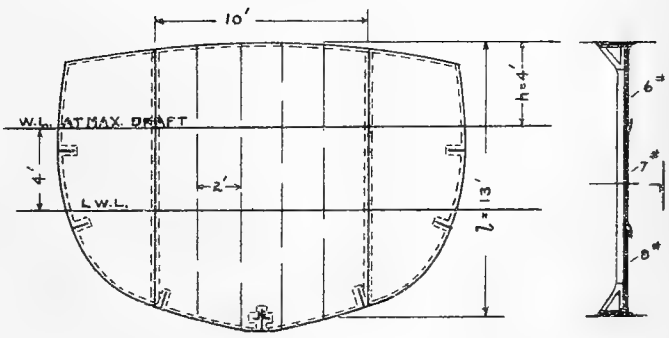
*To illustrate paper on "An Analysis of Tests of Water-tight Bulkheads with Practical Rules and Tables for their Construction," by Professor William Hovgaard, Member.*

## EXAMPLES OF APPLICATIONS OF THE TABLES.




l=15' h=5' s=2'-6" S=10.05 SQ.INS.IN.
STIFF.=7½"x3"x.425




l=13' h=-4'(NEG.) s=2' S=1.51 SQ.INS.IN.
STIFF.=4½"x3"x.300

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

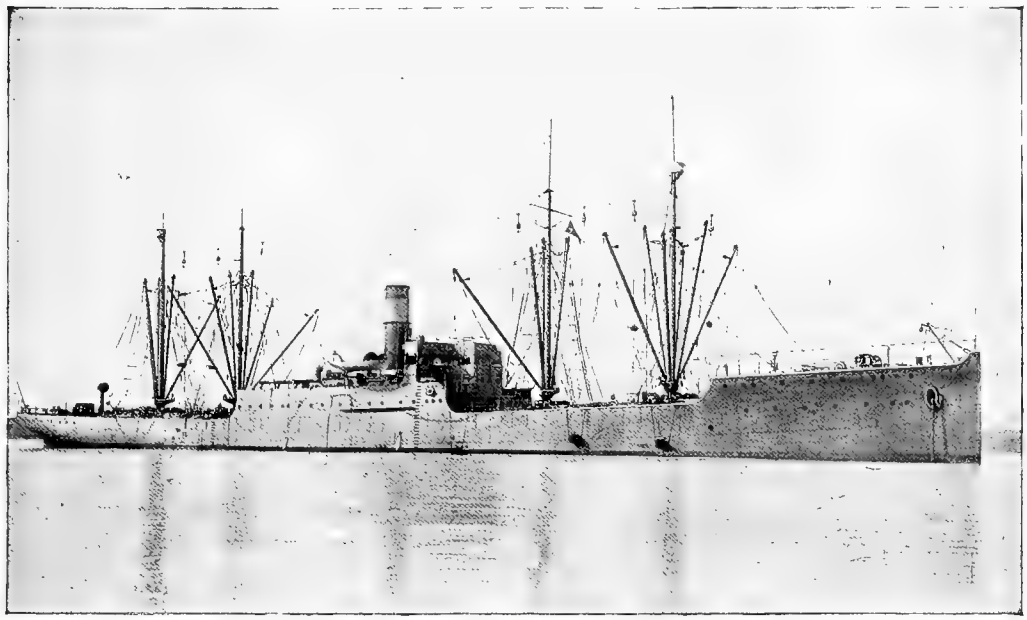


FIG. 1.—U S COLLIER VESTAL EQUIPPED WITH MARINE TRANSFERS.

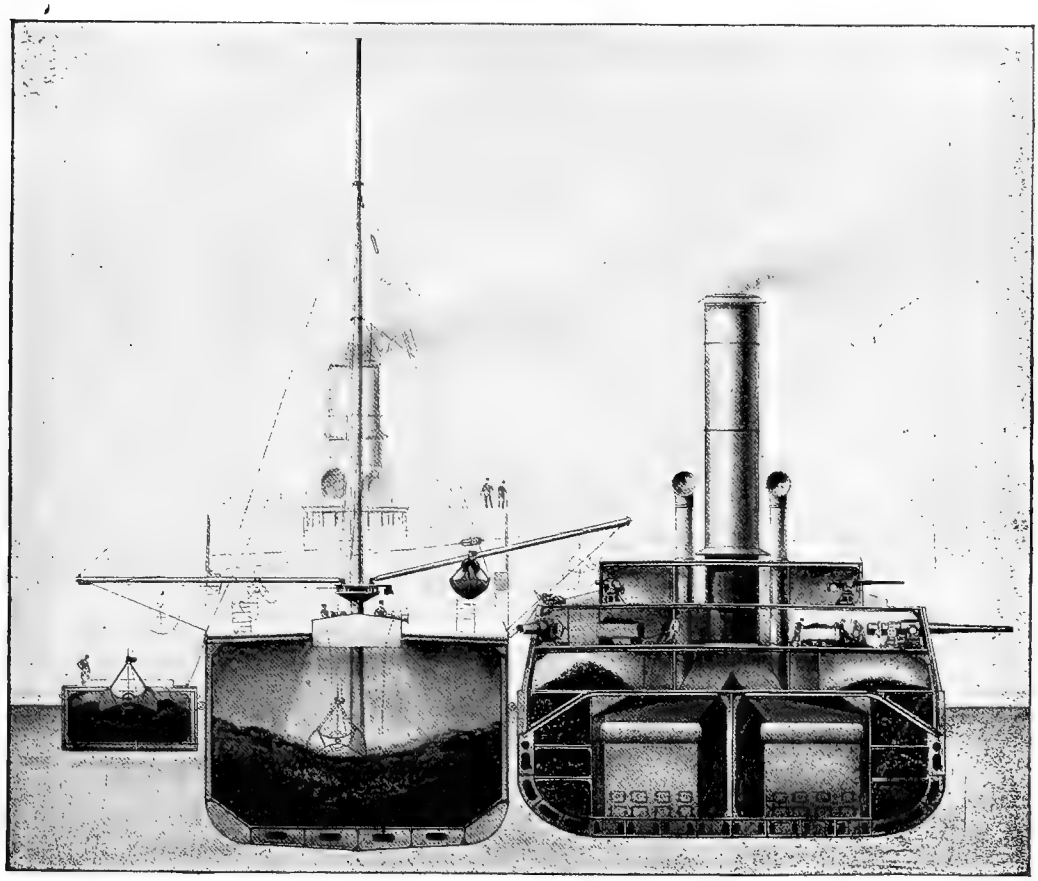


FIG. 2.—THE MARINE TRANSFER ON THE U. S. COLLIERS VESTAL AND PROMETHEUS.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

FIG. 3.—U S. COLLIER VESTAL AT ANCHOR, READY TO GO ALONGSIDE A BATTLESHIP TO COAL.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

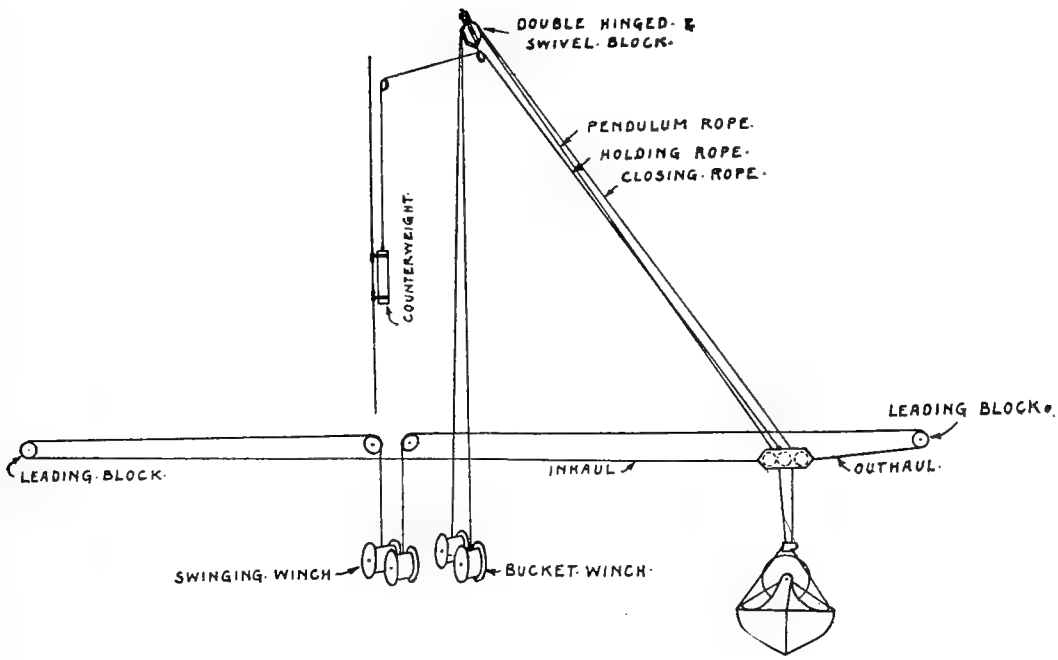



FIG. 4.—ROPE HEAD OF MARINE TRANSFER ON COLLIERS VESTAL AND PROMETHEUS.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

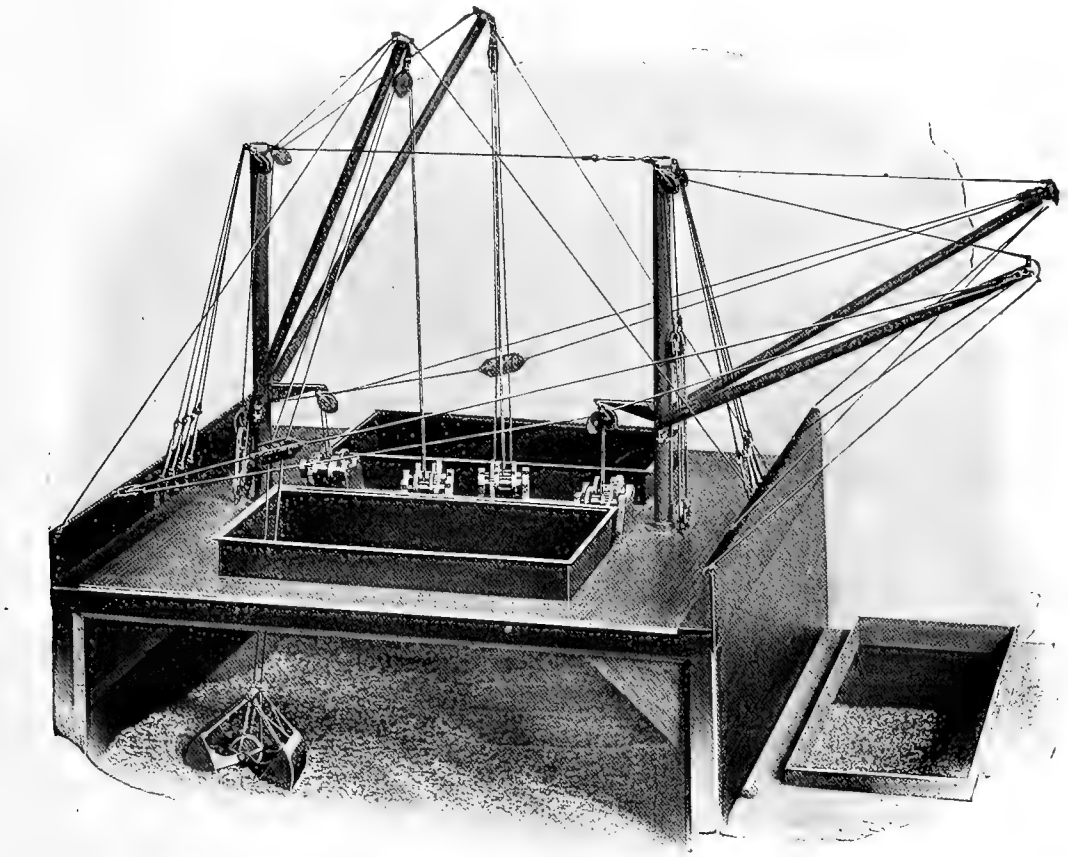


FIG. 5 —BUCKET DIGGING IN HOLD, COLLIERS MARS, VULCAN AND HECTOR.

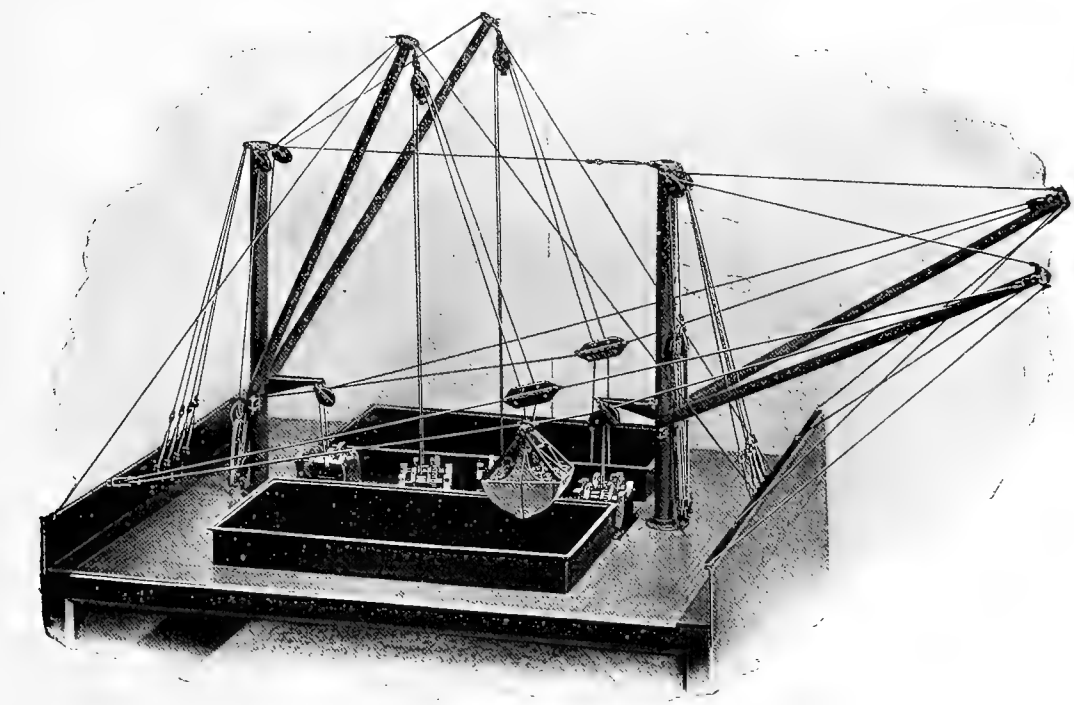


FIG. 6.—BUCKET BEING SWUNG OUTBOARD WITH LOAD OF COAL.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

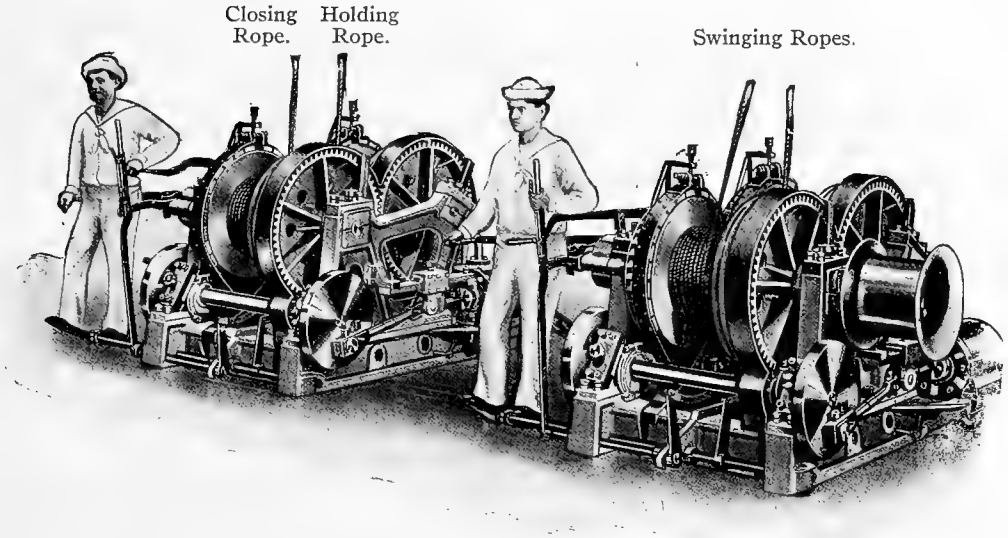



FIG. 7.—LIDGERWOOD-MILLER MARINE TRANSFER WINCHES.

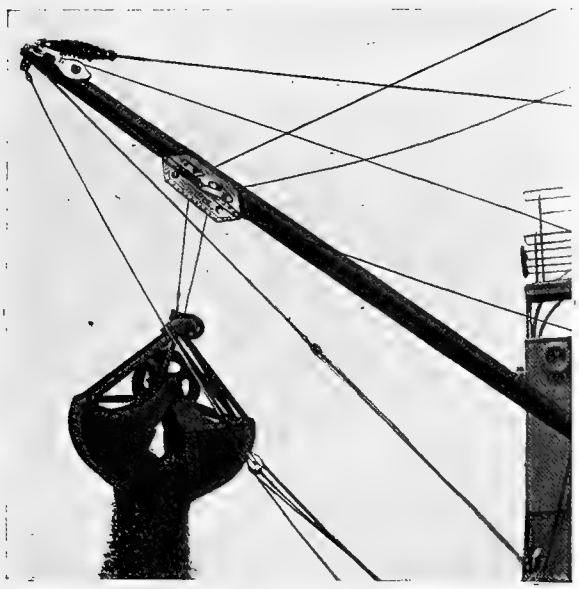


FIG. 8.—THE SELF-FILLING CLAMSHELL BUCKET.

Digs and dumps one ton of coal.

FIG. 9.—DOUBLE-HINGED SWIVEL BLOCK.

Attached to boom or stay over hatch.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

FIG. 10.—U. S. COLLIER VESTAL COALING THE U. S. S. MICHIGAN, USING THE MARINE TRANSFER WITH SELF-DIGGING CLAMSHELL BUCKETS.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

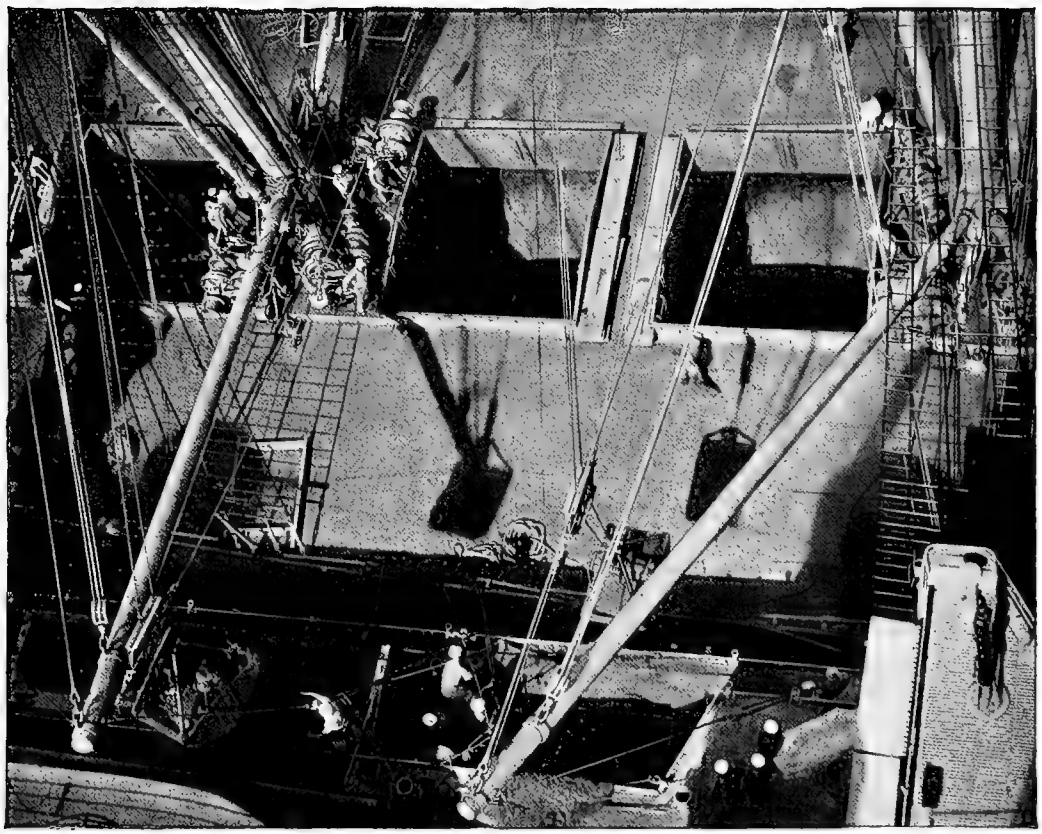


FIG. 11.—BIRD'S-EYE VIEW FROM TOP OF FIRE CONTROL MAST OF U. S. S. MICHIGAN.
Two self-filling grab buckets shown dumping through open skylights.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

FIG. 12.—THE MARINE TRANSFER ON COLLIER MARS DELIVERING COAL IN BULK TO THE U. S. S. PANTHER.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

FIG 13.—THE MARINE TRANSFER ON COLLIER MARS DELIVERING COAL TO U. S. S. PANTHER.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

FIG. 14 —COALING THE U. S. S. PANTHER. THE CLAM-SHELL BUCKET FROM THE MARS DELIVERING COAL DIRECTLY INTO HOPPER WAGONS.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

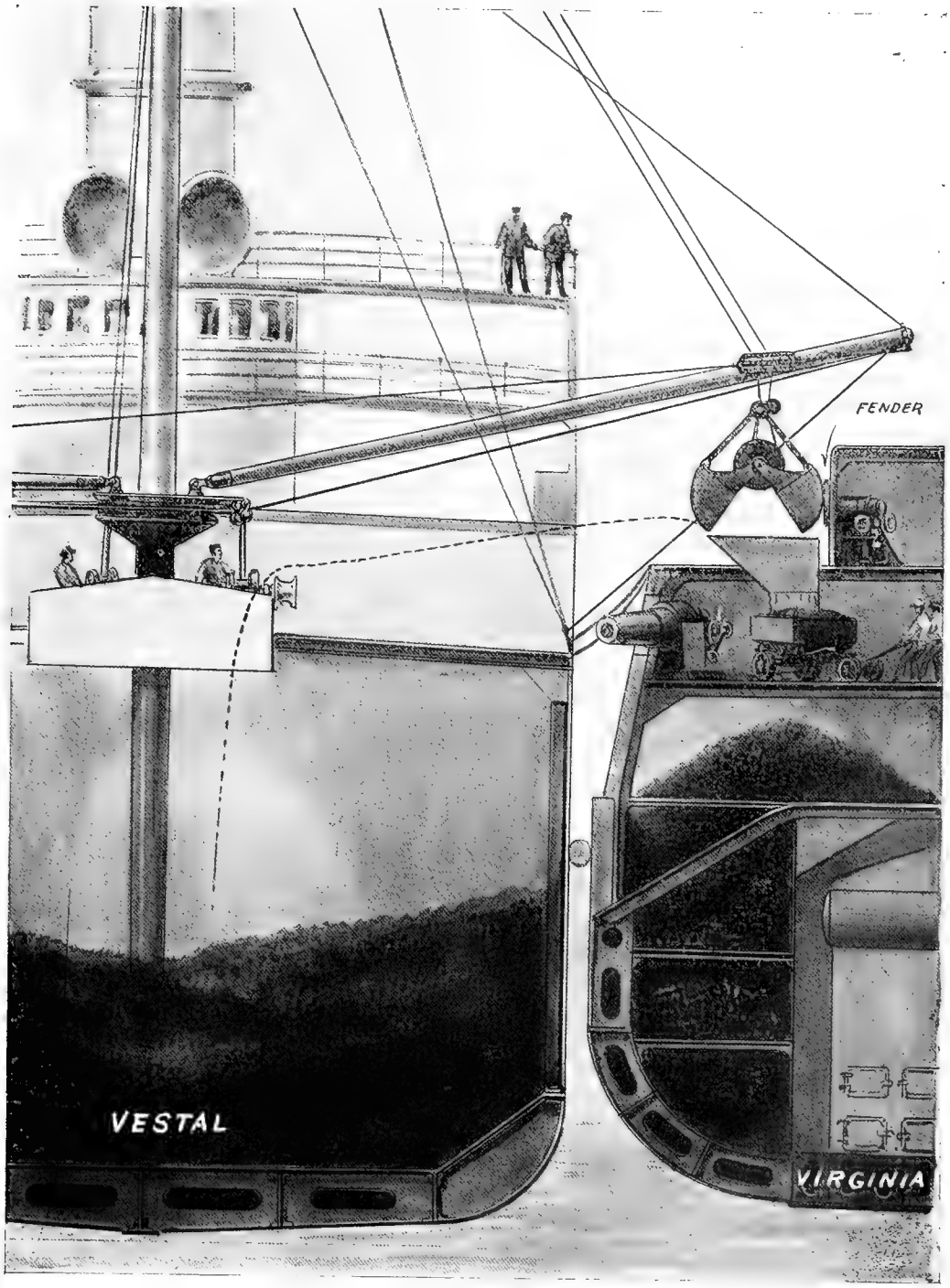



FIG. 15.—SUGGESTION FOR A METHOD OF COALING IN BULK, OMITTING ALL HAND SHOVELLING.

*To illustrate paper on "Coaling Warships from Colliers in Harbors," by Spencer Miller, Esq., Member.*

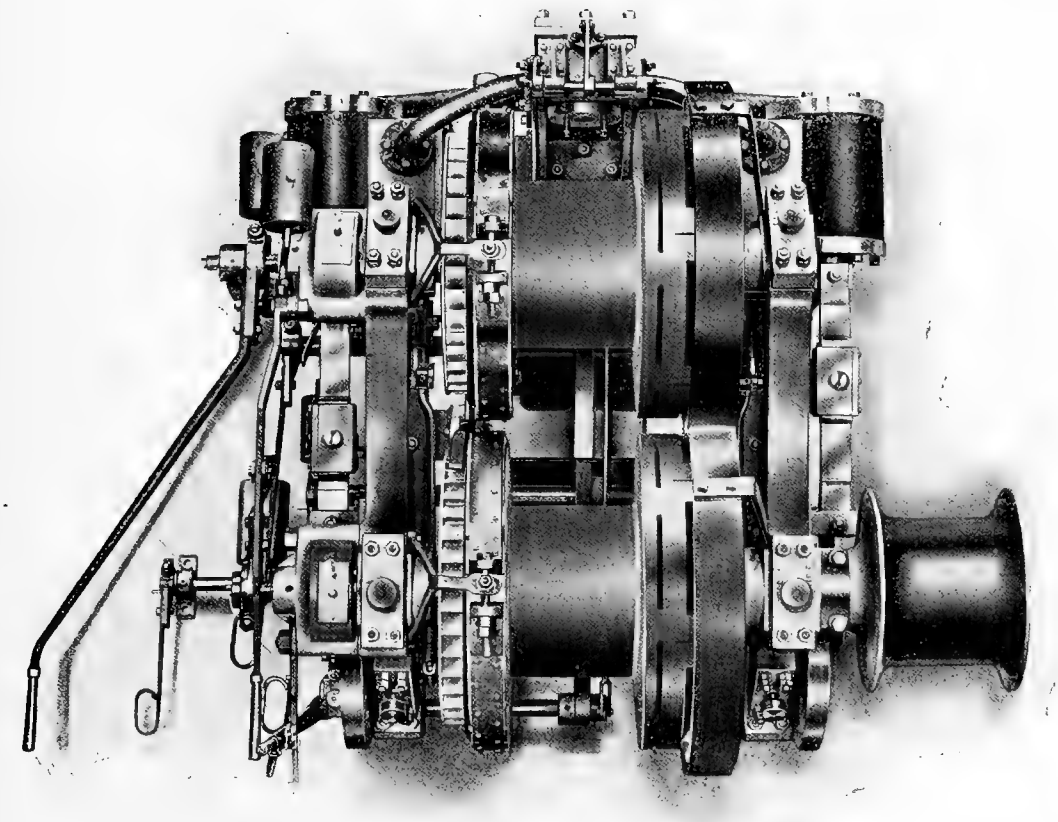
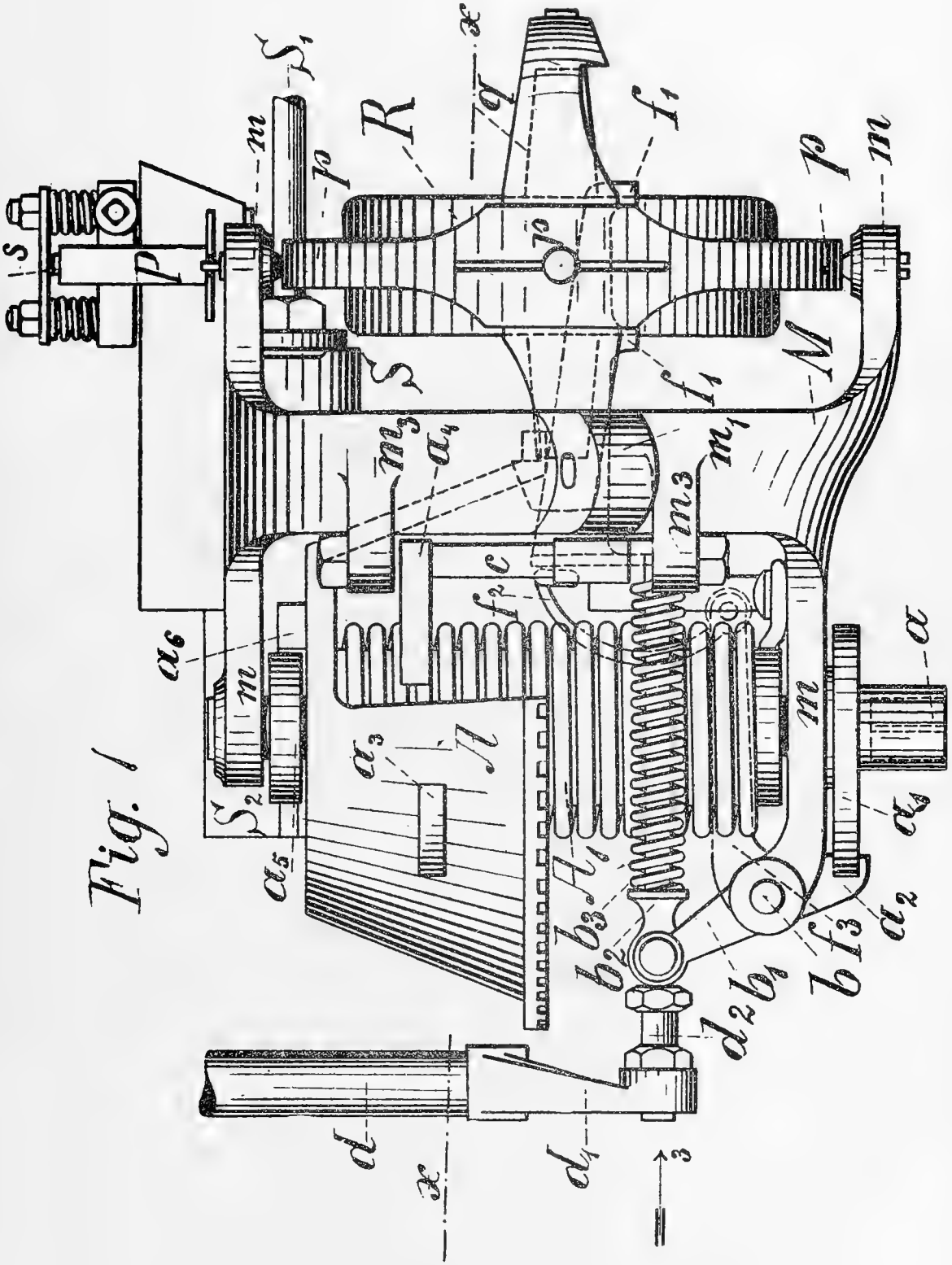


FIG. 16.—PLAN VIEW OF WINCHES ON VESTAL, PROMETHEUS, VULCAN, HECTOR, AND MARS.

*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*



*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*

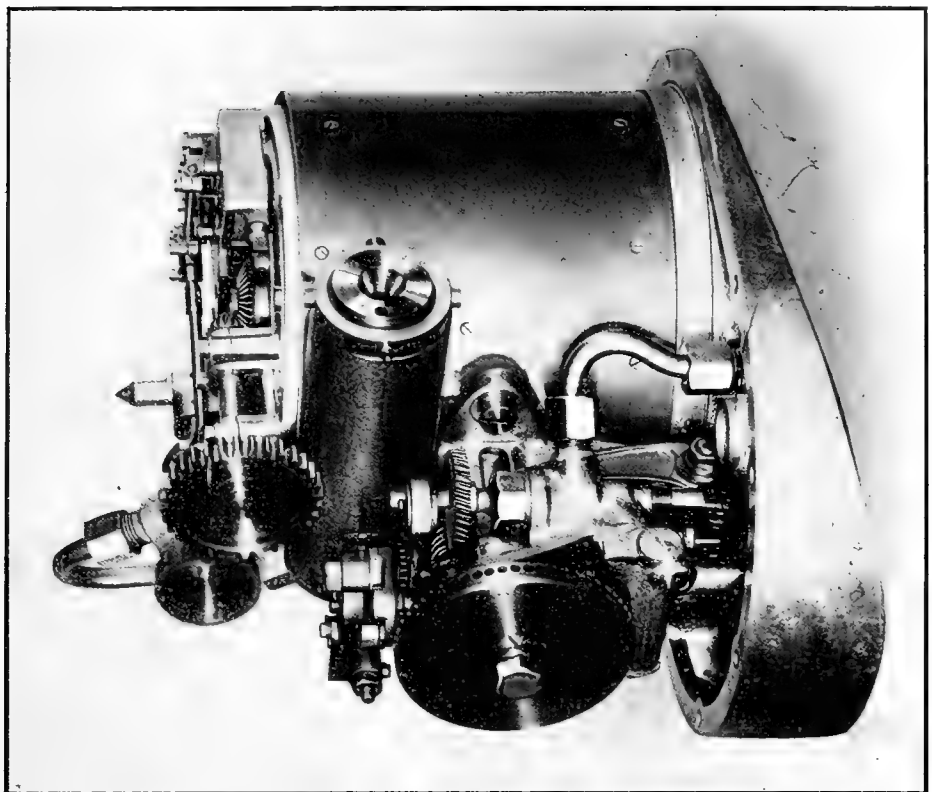


FIGURE 3.

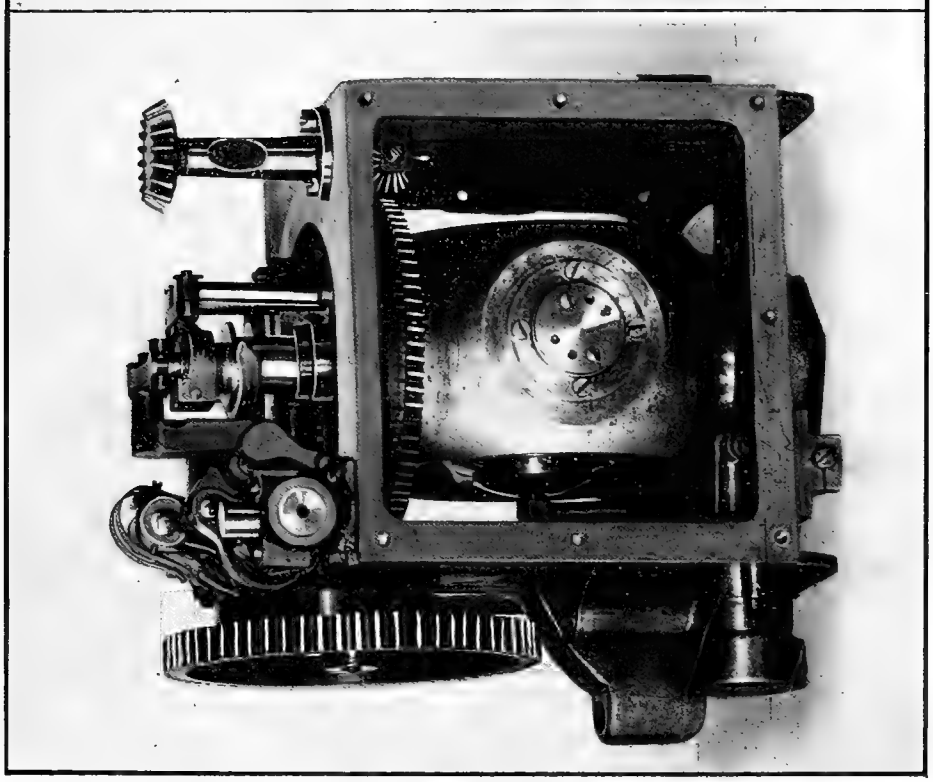
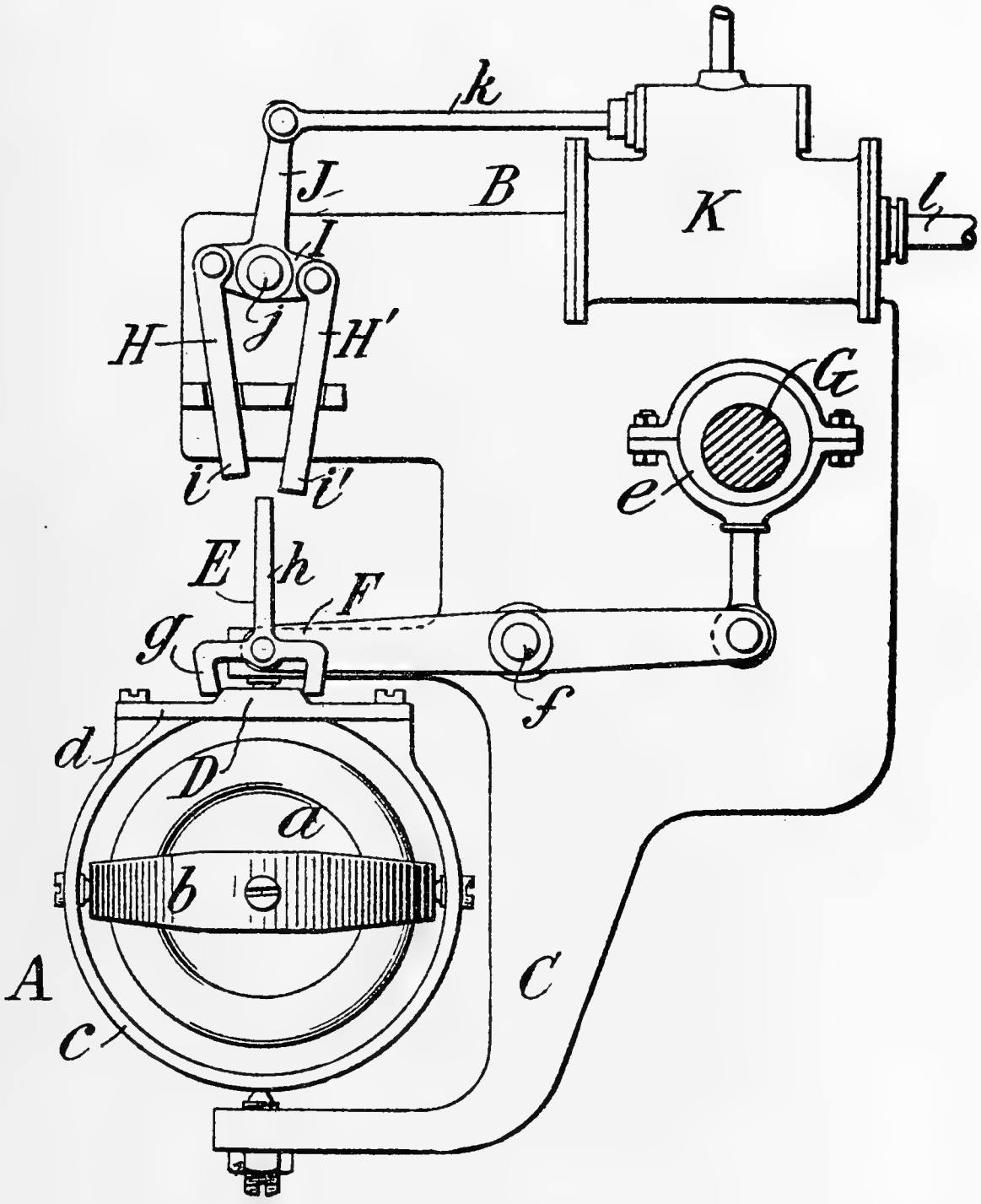


FIGURE 2.

*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*



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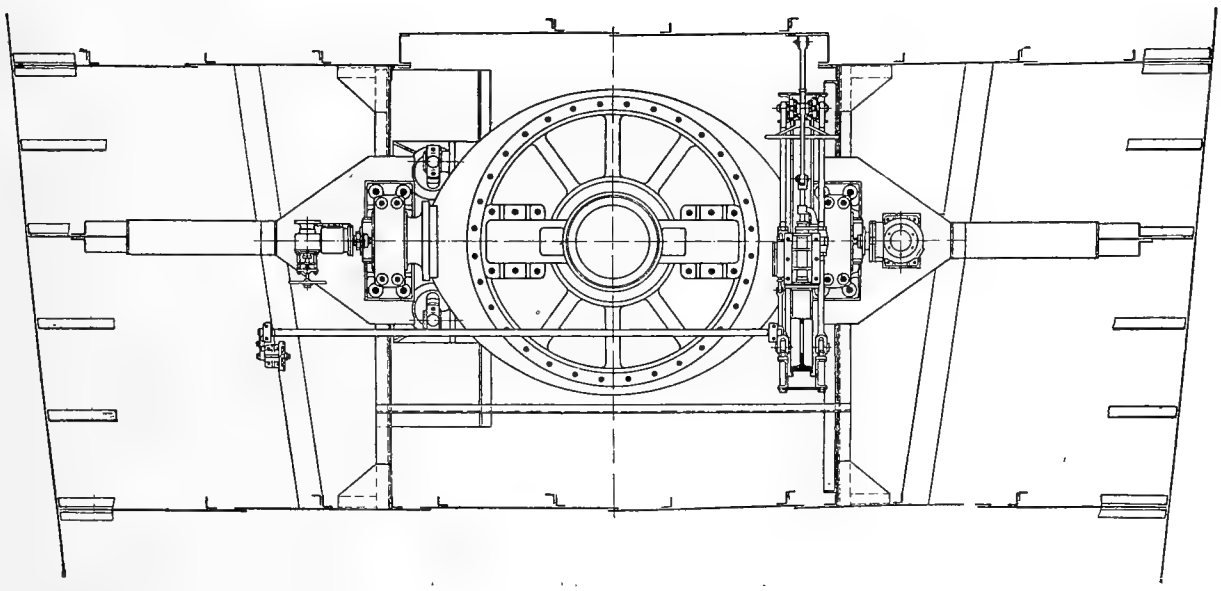

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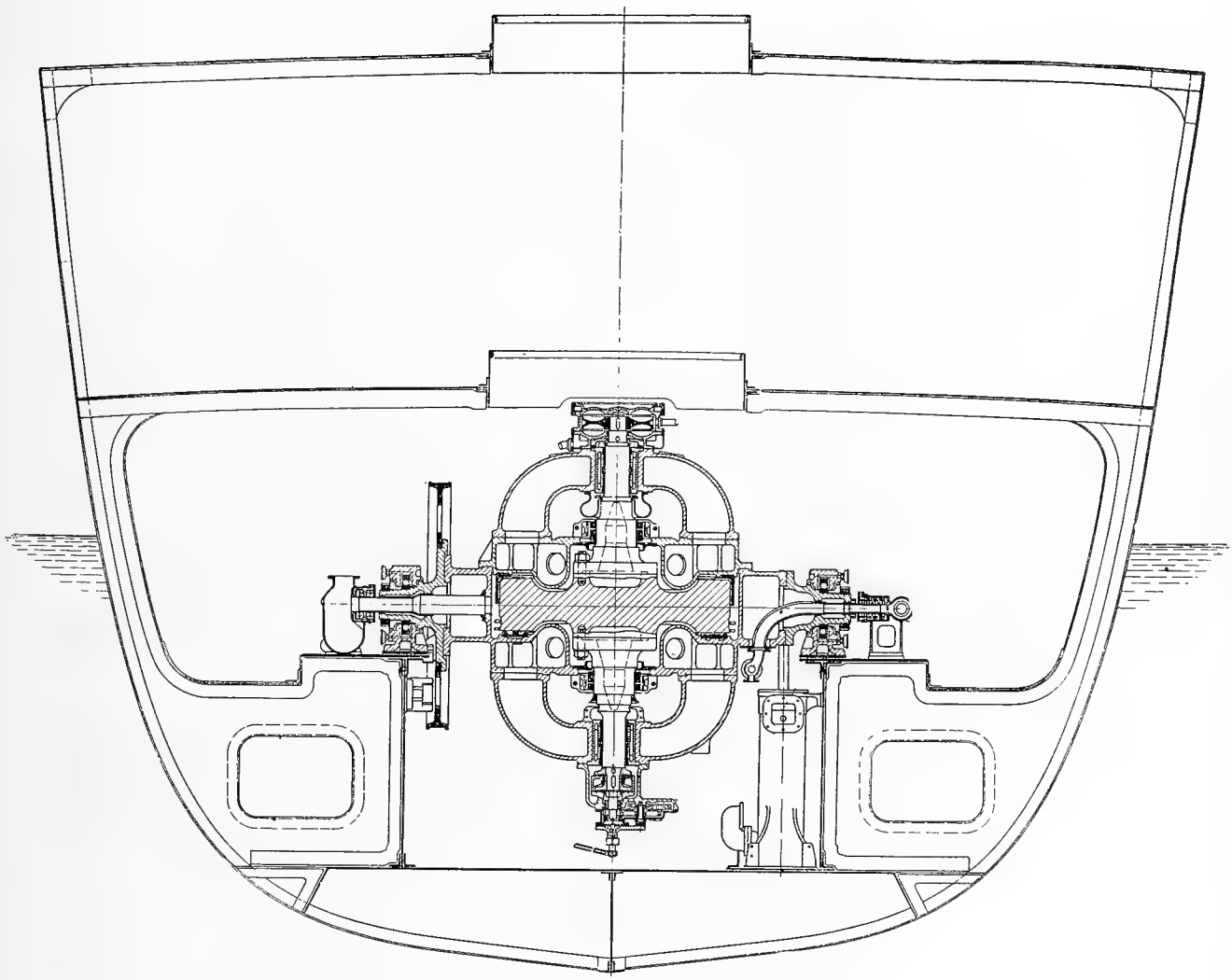

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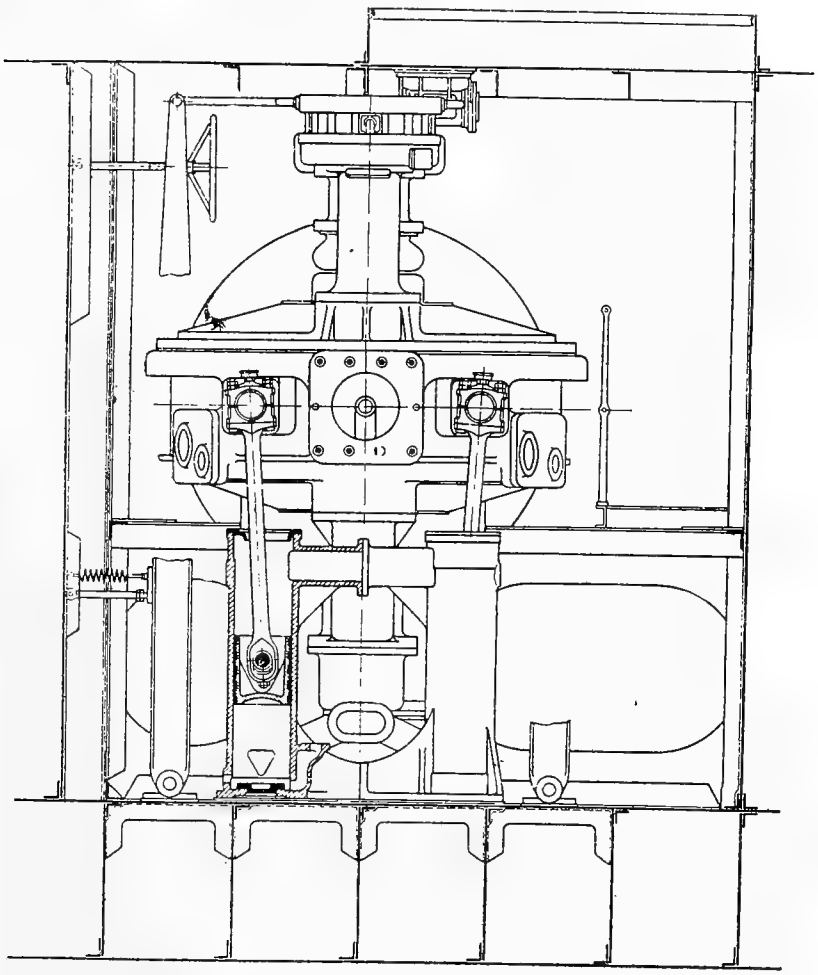


FIGURE 8.

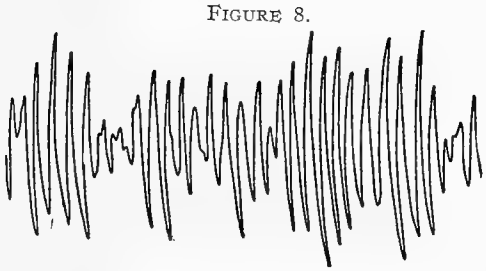
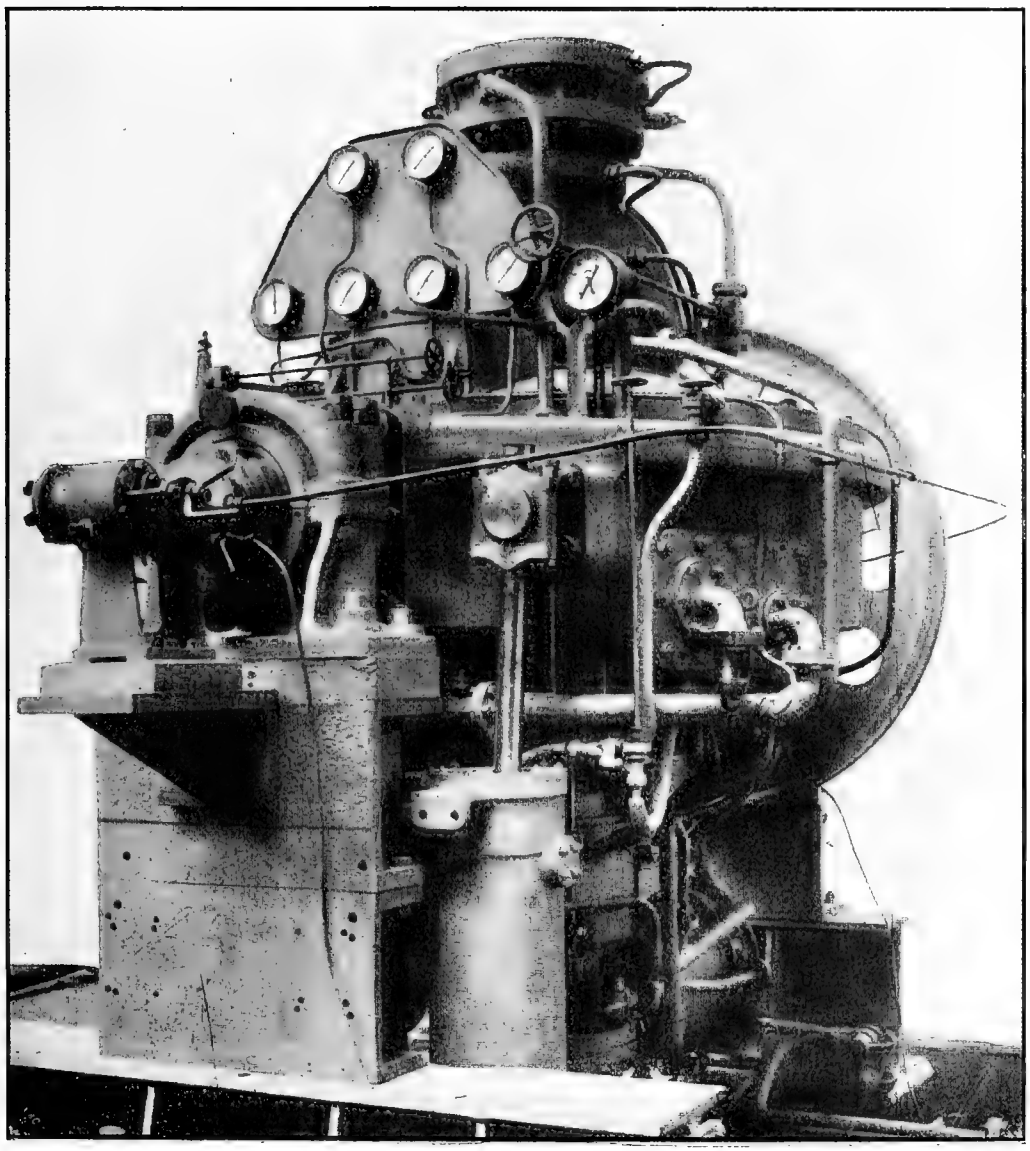


FIGURE 10.

*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*



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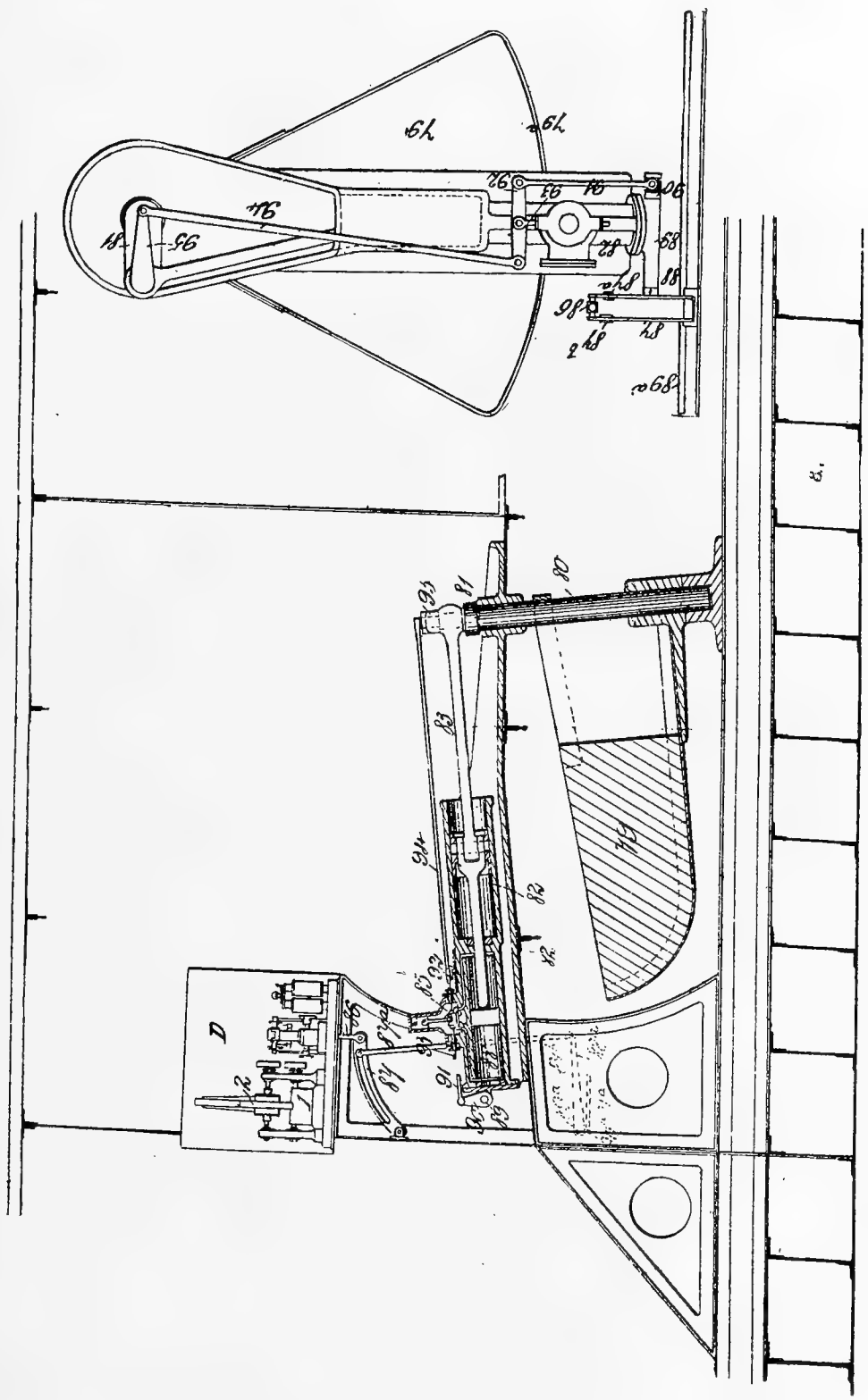

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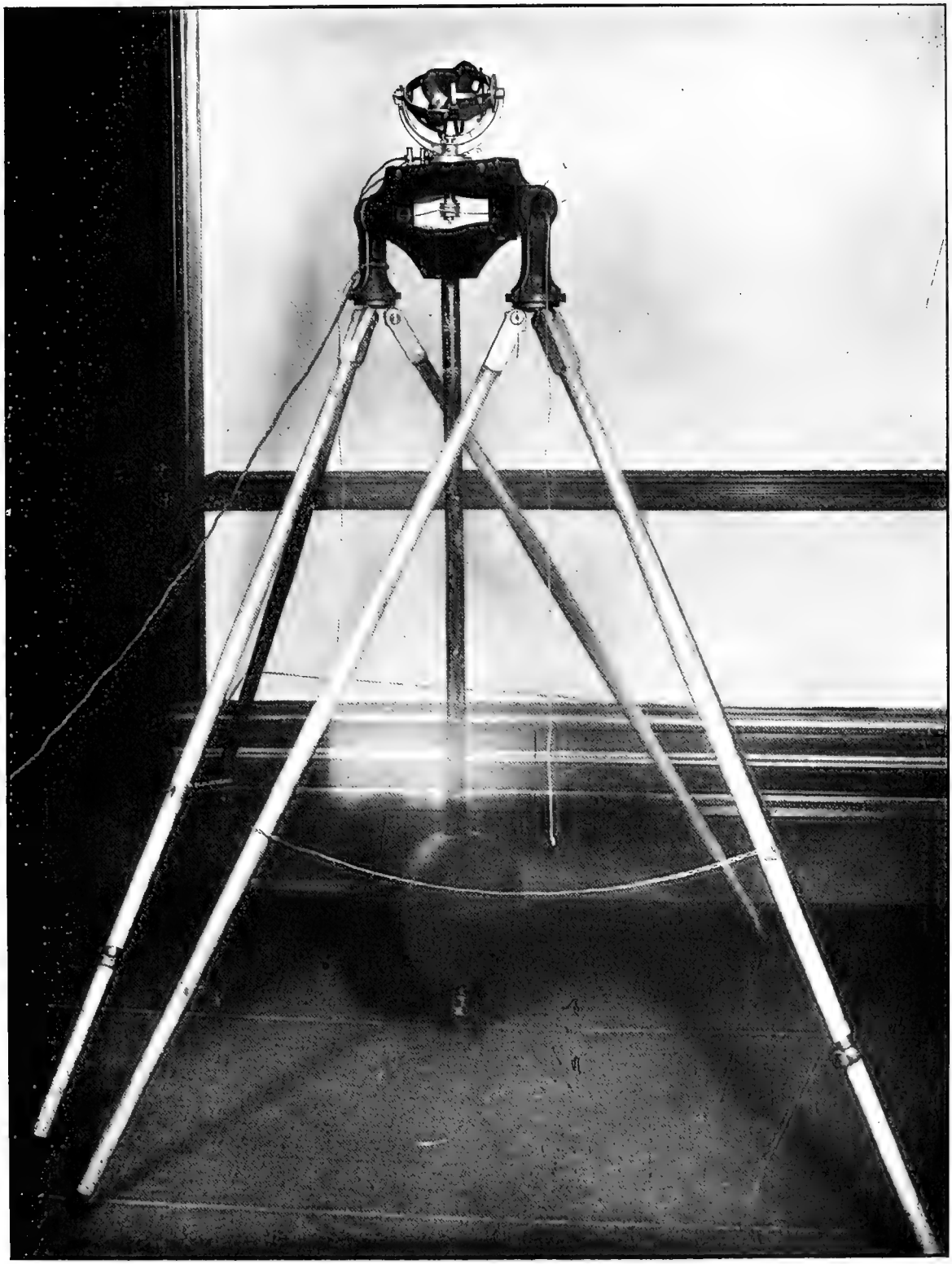

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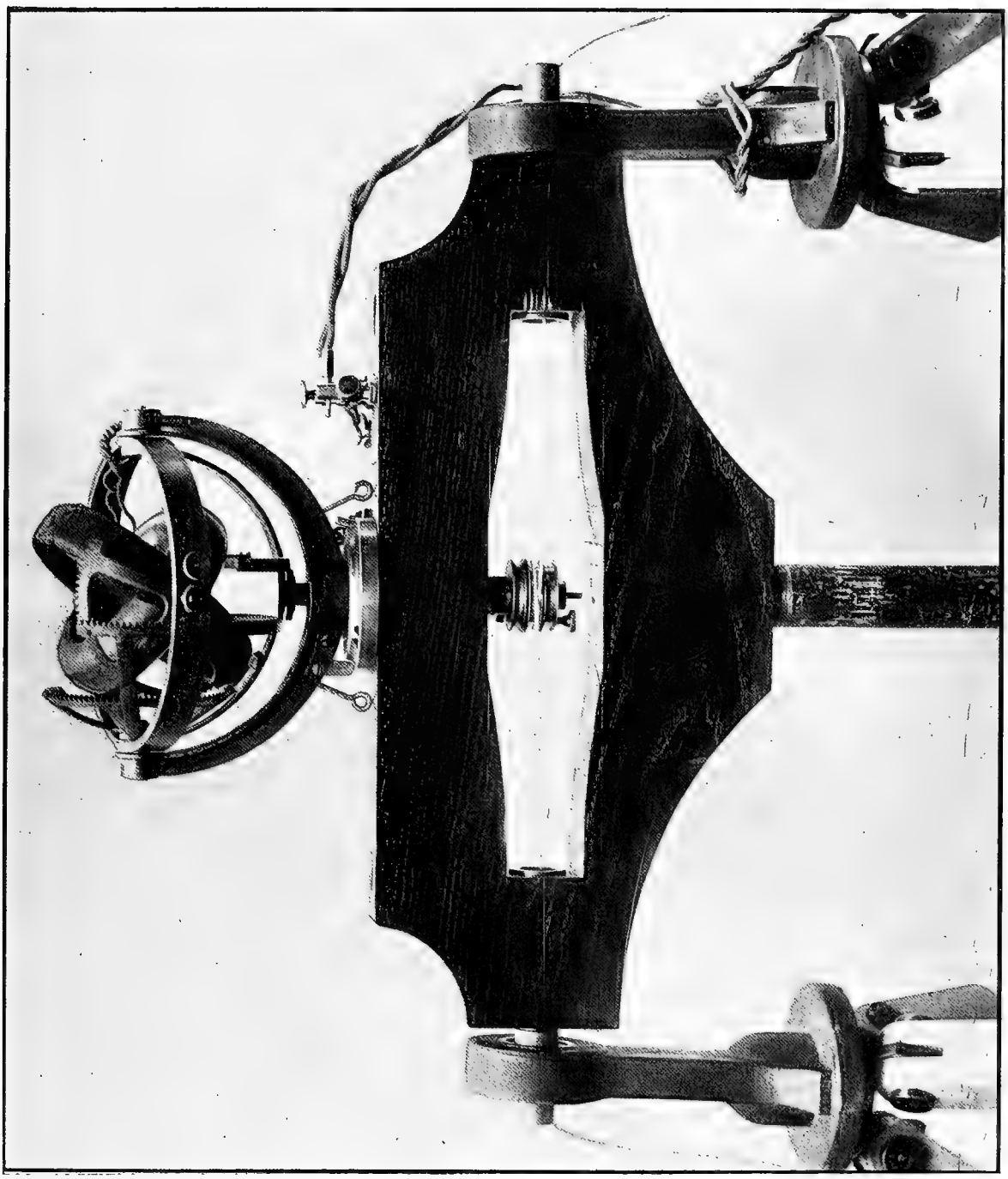

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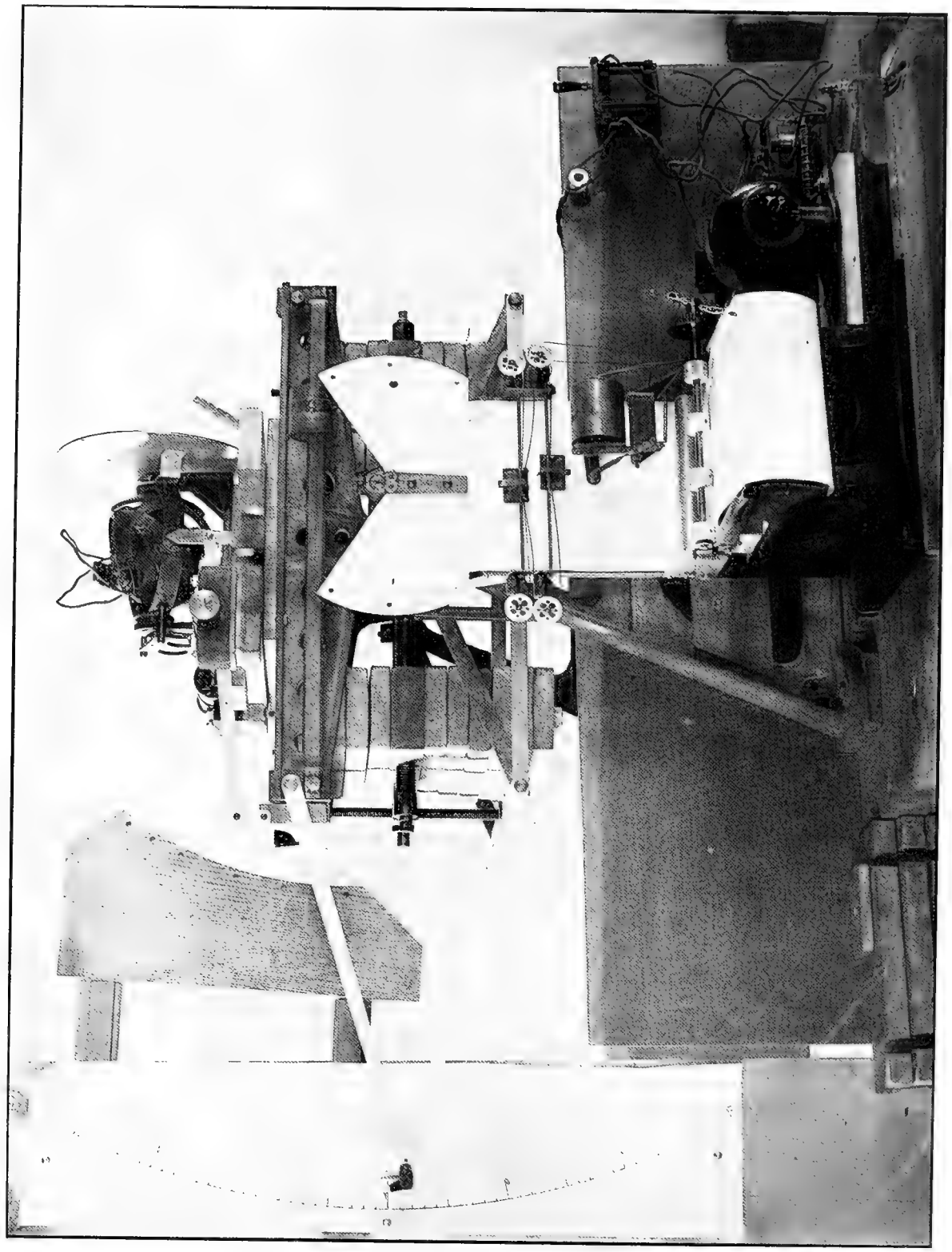

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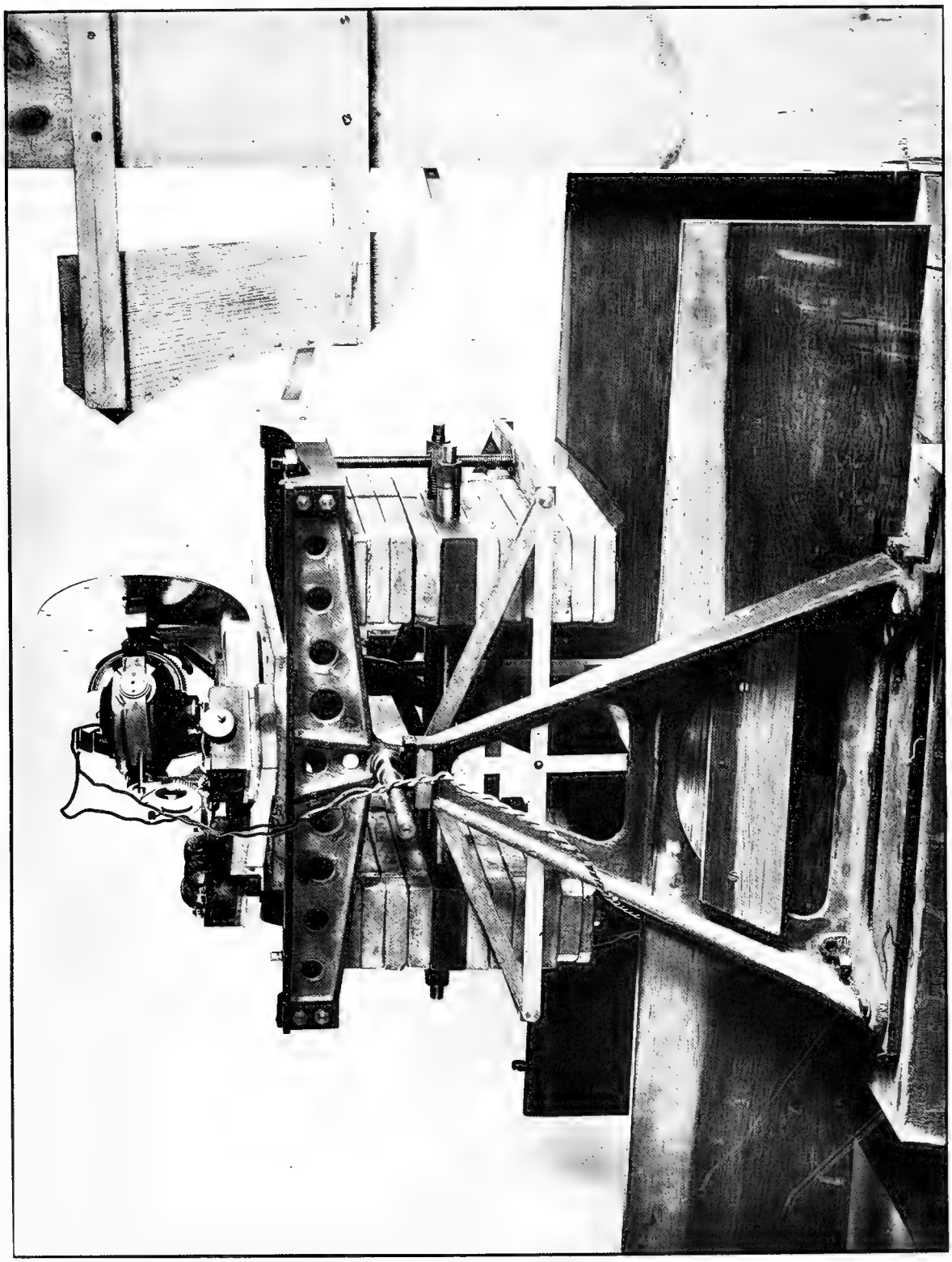


*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*

$$\frac{M'_Z}{m r^2} = (\alpha^2+\beta^2)\sin\psi\cos\psi\cos\phi - 2\alpha\beta\sin^2\psi\sin\phi + \gamma\sin^2\psi\cos\phi + \delta\sin\psi\cos\psi\sin\phi - \alpha^2\sin\psi\cos\psi\cos\phi + \gamma\cos^2\psi\cos\phi.$$

$$= \beta^2\sin\psi\cos\psi\cos\phi - 2\alpha\beta\sin^2\psi\sin\phi + \gamma\cos\phi + \delta\sin\psi\cos\psi\sin\phi$$

Now as before put $m = \frac{w}{2\pi g} d\psi$

Then

$$M'_X = \frac{w r^2}{2\pi g}\left[\beta^2\sin\phi\sin\psi\cos\psi d\psi + 2\alpha\beta\cos\phi\sin\psi d\psi + \gamma\sin\phi d\psi - \delta\cos\phi \int \sin\psi\cos\psi d\psi\right]$$

$$M'_Y = \frac{w r^2}{2\pi g}\left[-2\alpha\beta\sin\psi\cos\psi d\psi + \delta\cos^2\psi d\psi\right]$$

$$M'_Z = \frac{w r^2}{2\pi g}\left[\beta^2\cos\phi\sin\psi\cos\psi d\psi - 2\alpha\beta\sin\phi\sin^2\psi d\psi + \gamma\cos\phi d\psi + \delta\sin\phi \int \sin\psi\cos\psi d\psi\right]$$

Evidently the moments for a complete ring of radius r and weight w will be obtained by integrating the above expressions with respect to $\psi$ from 0 to $2\pi$.

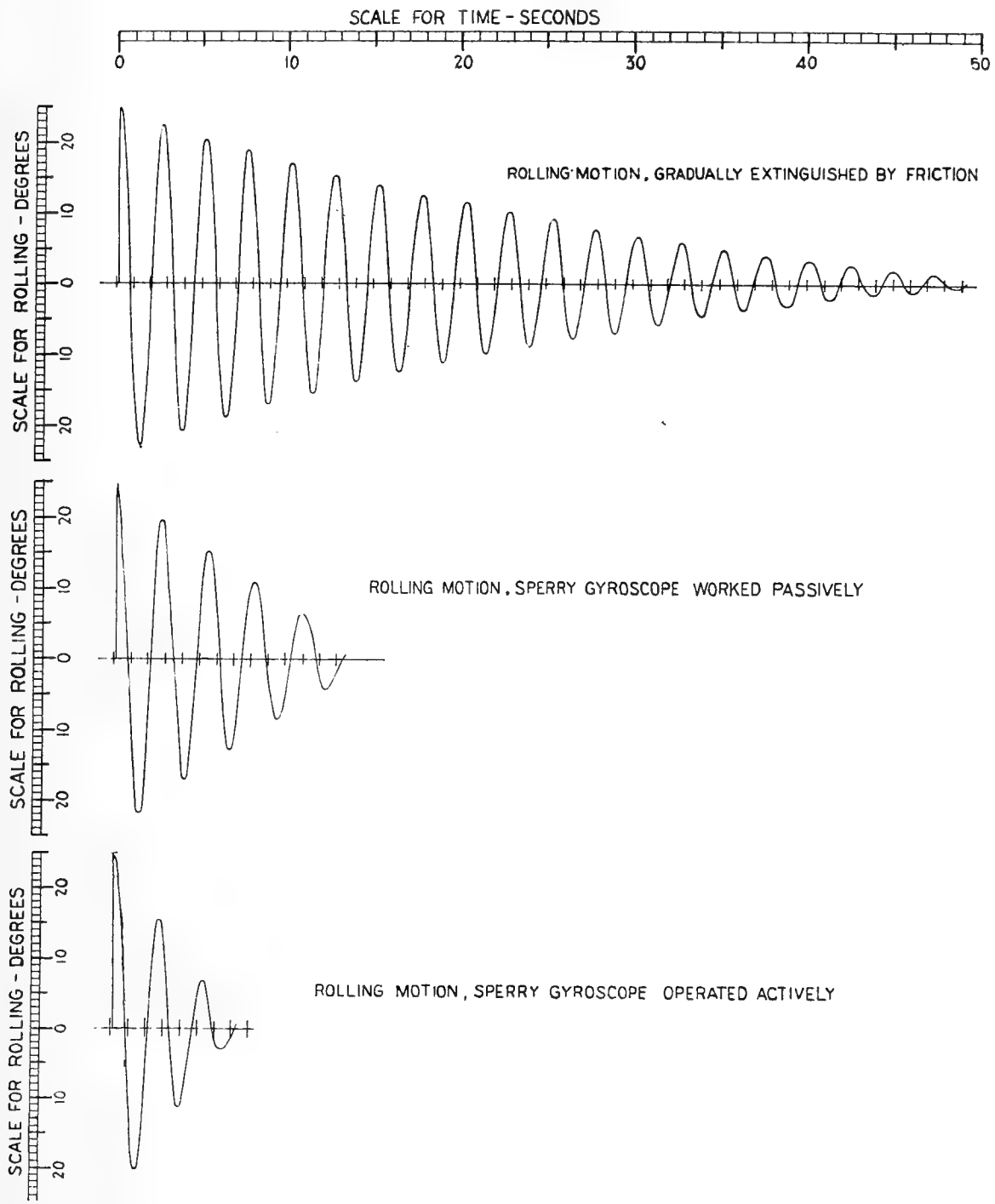
Now

$$\int_0^{2\pi} \sin\psi\cos\psi d\psi = 0 \qquad \int_0^{2\pi} \sin^2\psi d\psi = \pi = \int_0^{2\pi} \cos^2\psi d\psi$$

Let $M_X$ $M_Y$ $M_Z$ denote the moments for the complete ring. Then evidently

$$M_X = \frac{w r^2}{2\pi g}\left[2\pi\alpha\beta\cos\phi + 2\pi\gamma\sin\phi\right] = \frac{w}{g} r^2\left\{\alpha\beta\cos\phi + \gamma\sin\phi\right\}$$

*To illustrate paper on "The Gyroscope for Marine Purposes," by Elmer A. Sperry, Esq., Member.*



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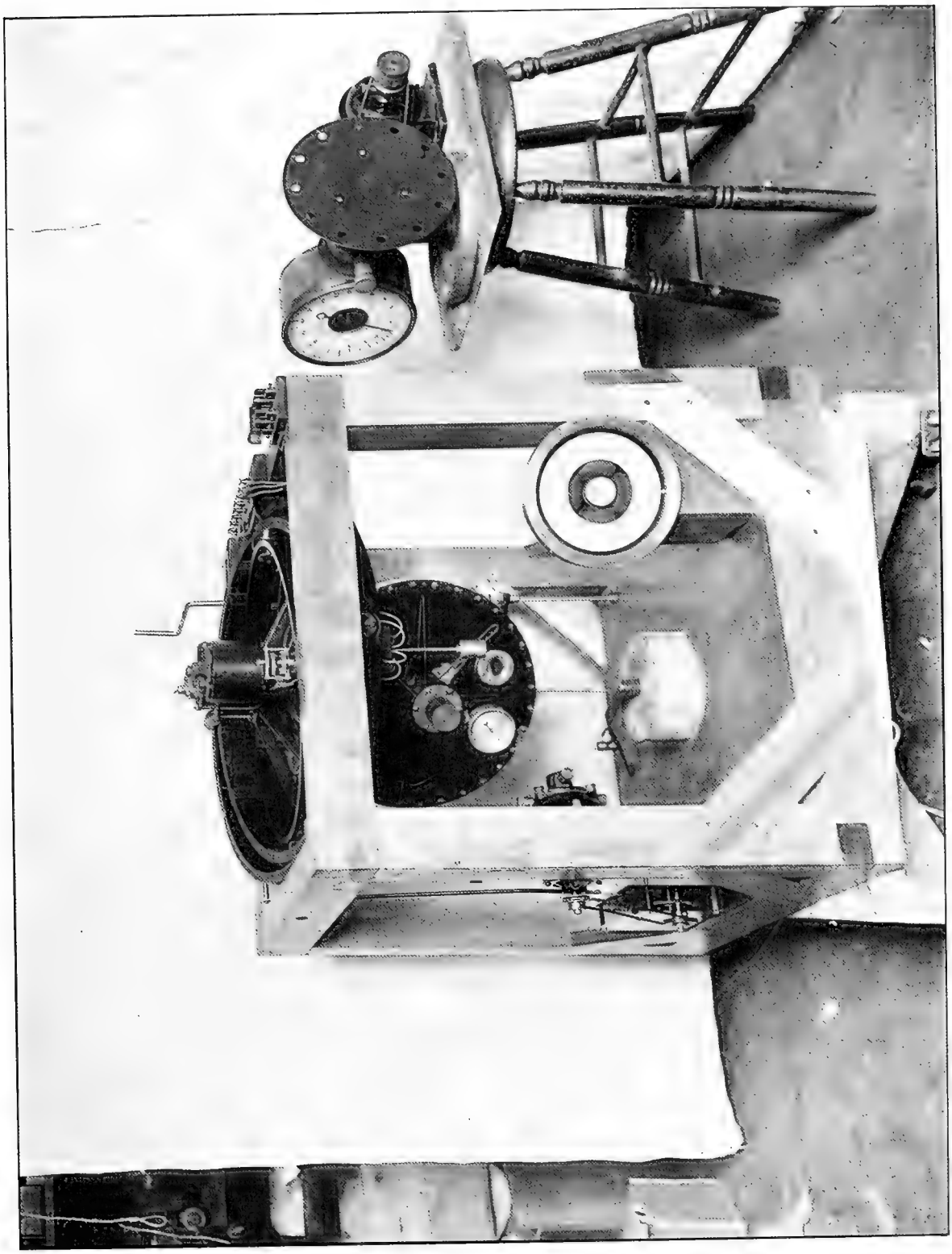

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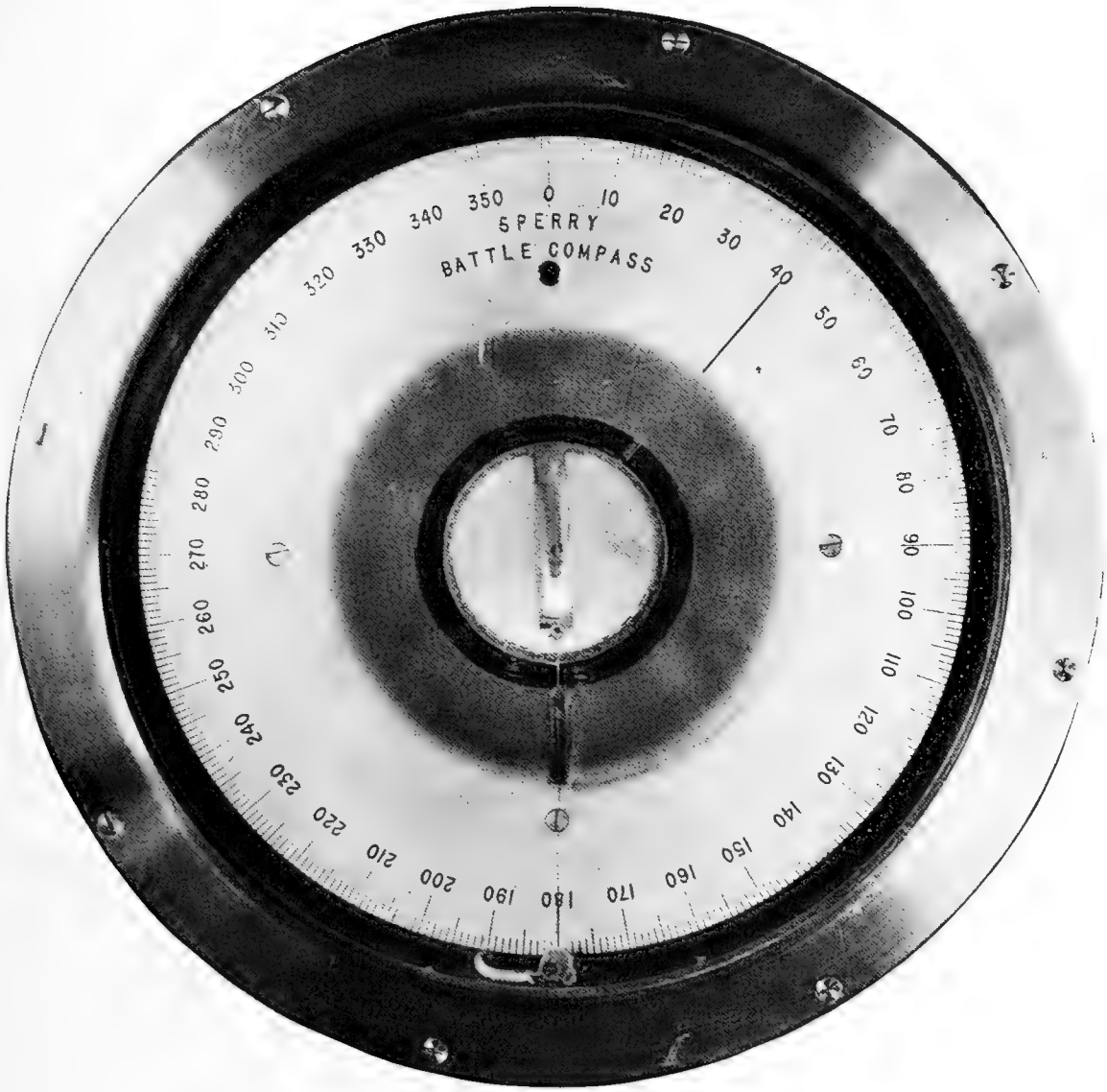
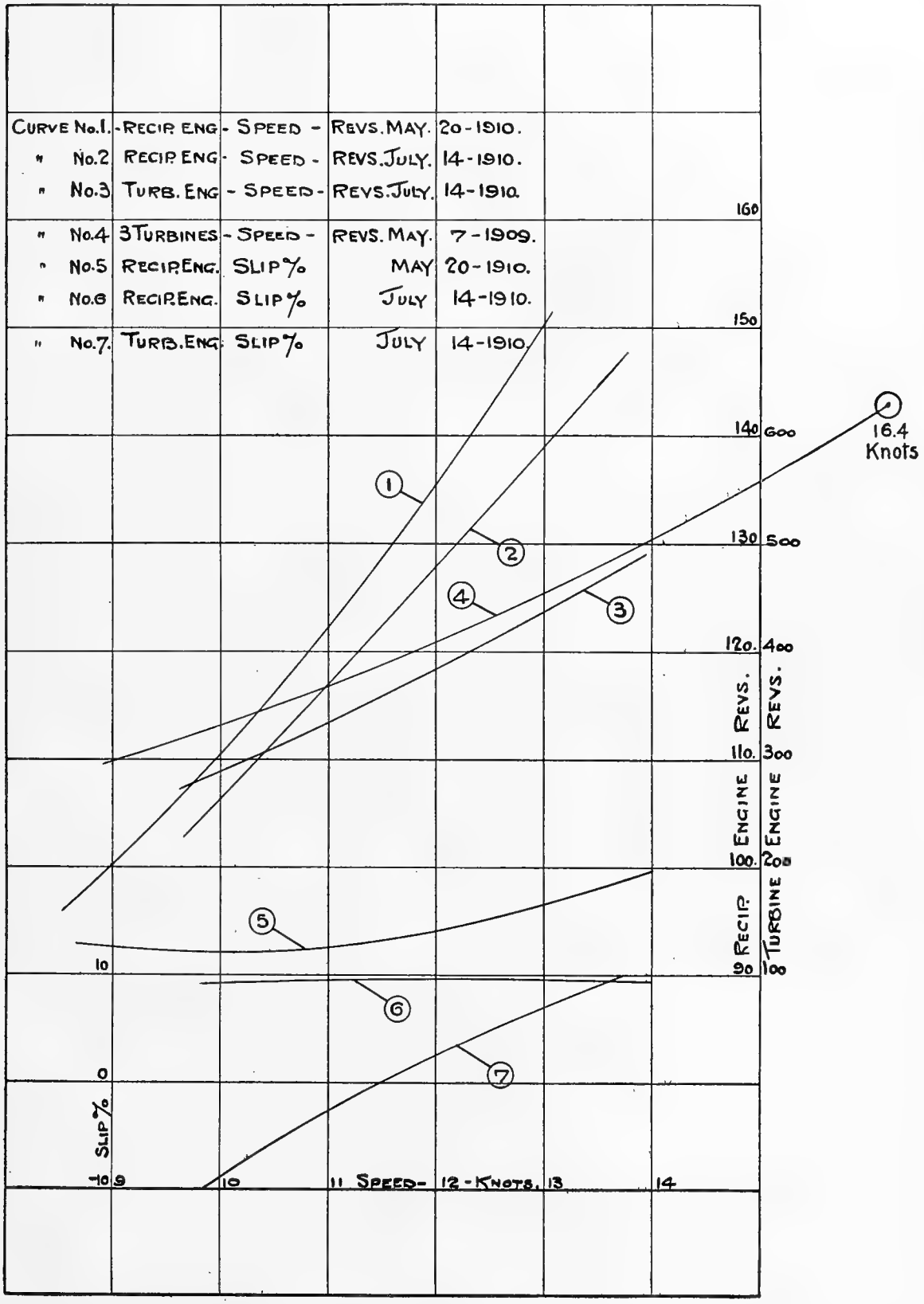


*To illustrate paper on "Comparative Results in Steam and Coal Consumption with Turbines, Reciprocating Engines and a Combination of the Two on the Steam Yacht Vanadis," by Clinton H. Crane, Esq., Member.*



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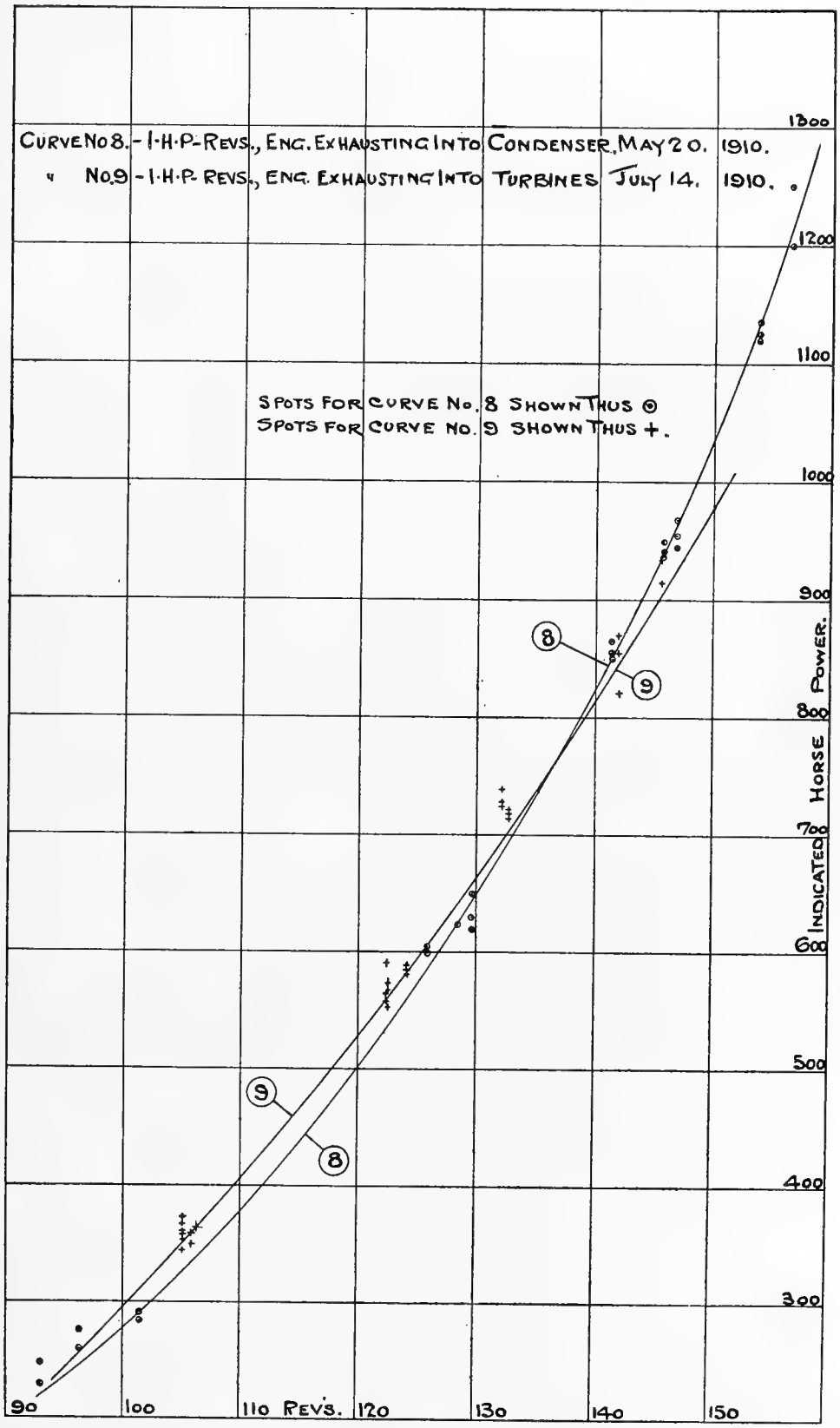

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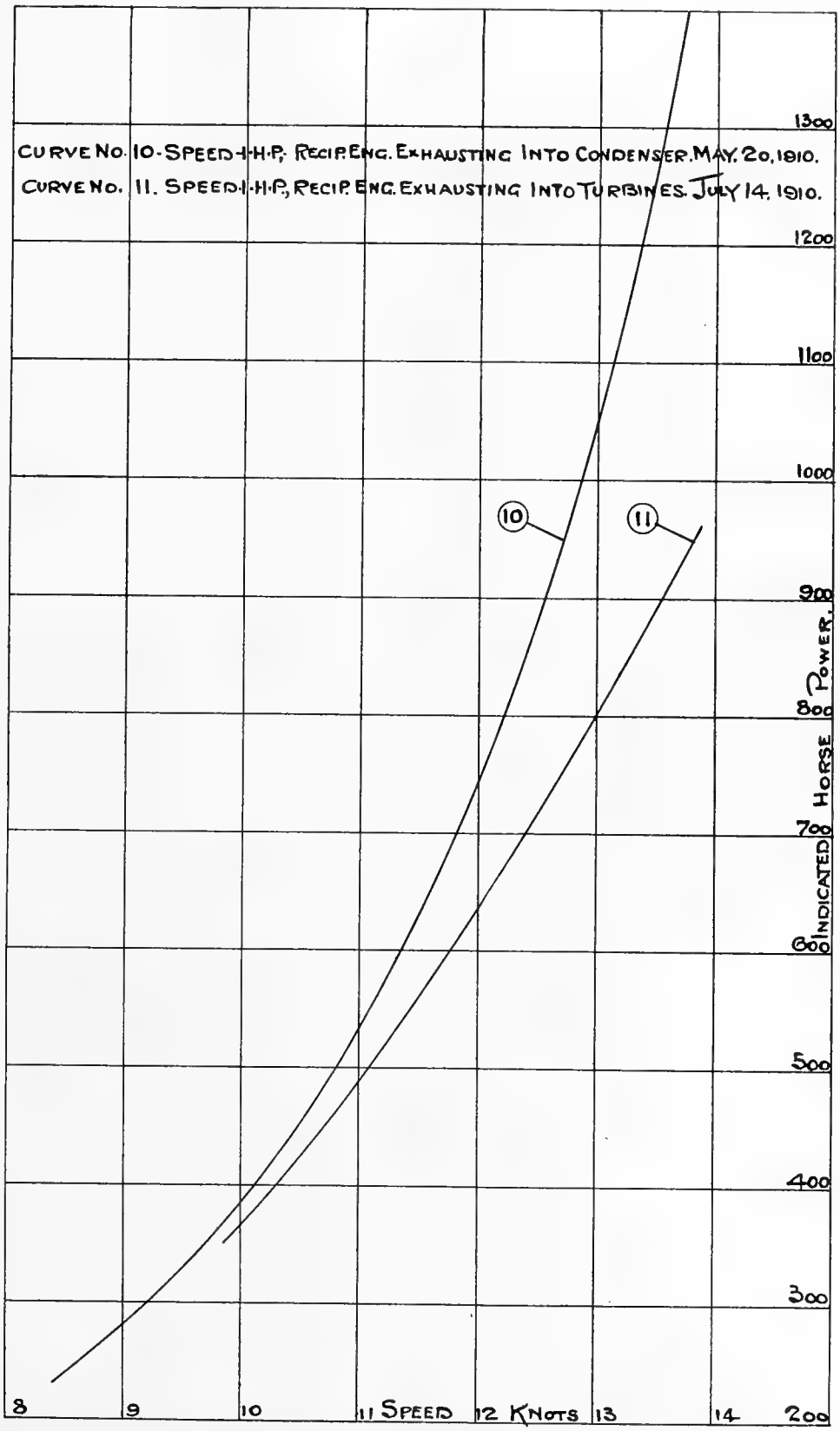

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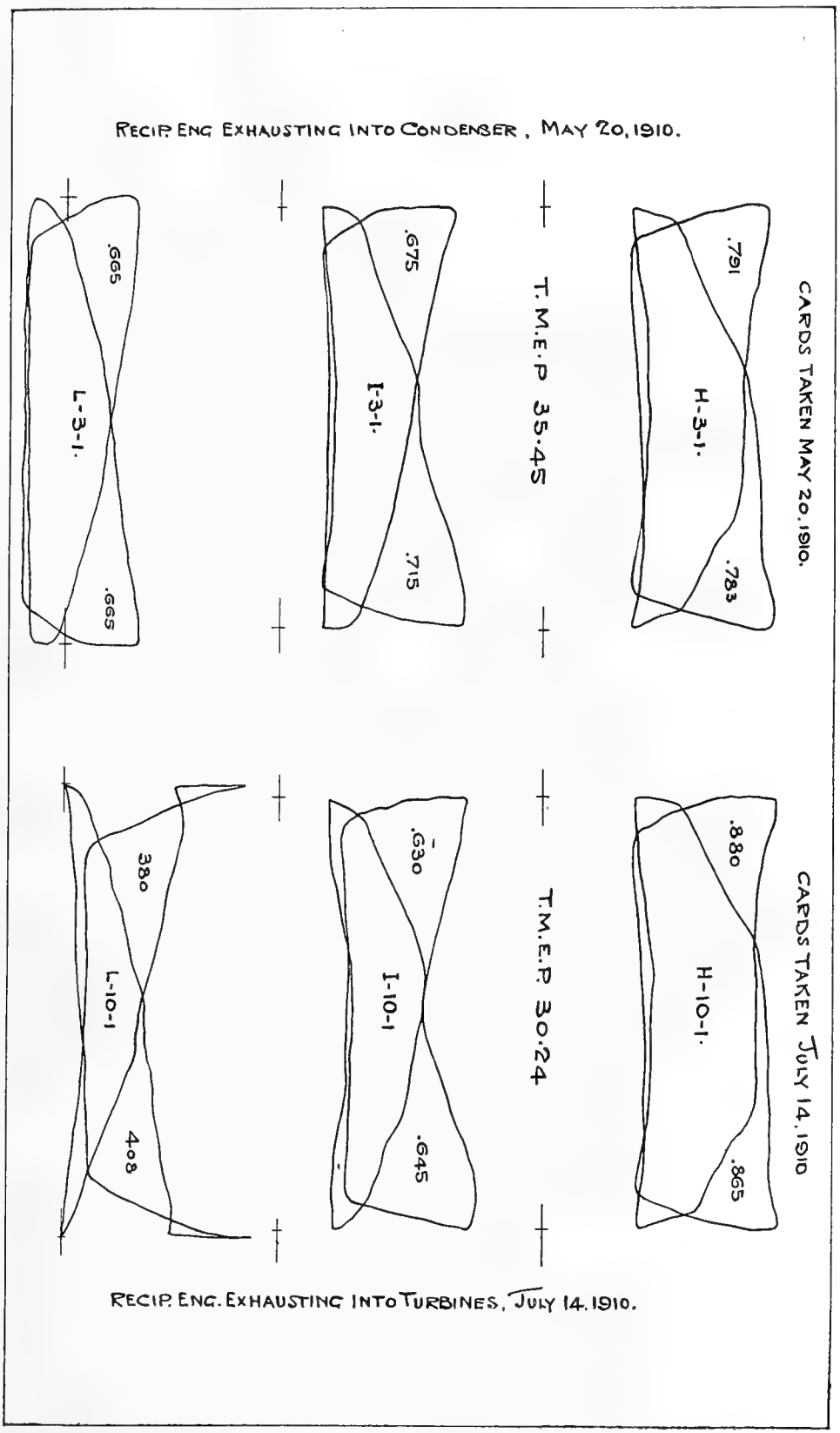


*To illustrate paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*

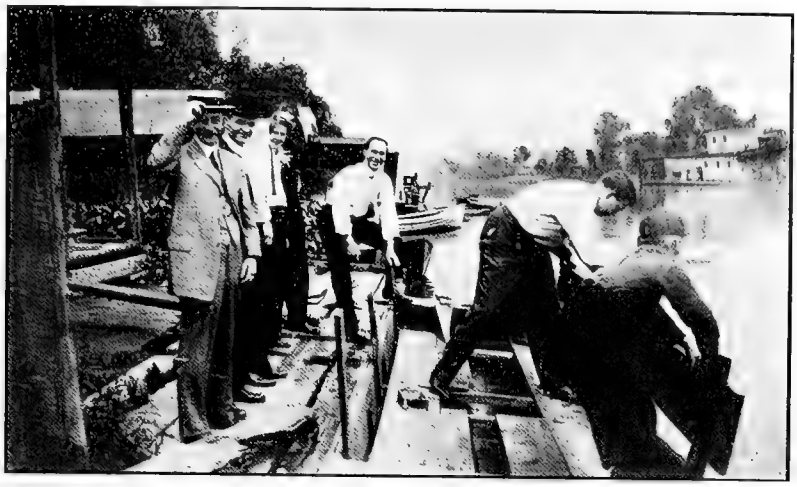


FIG. 1—GETTING PUNT READY FOR TEST.

FIG. 2—FIREMEN AT WORK.

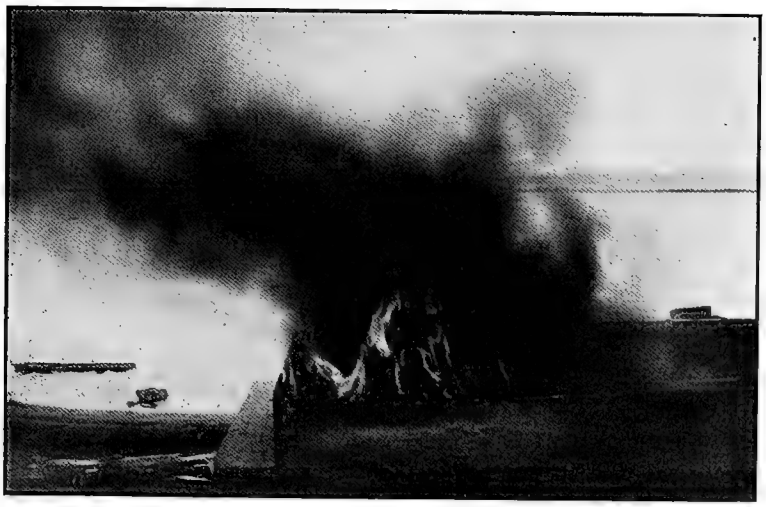


FIG. 3—GASOLINE STILL BLAZING AFTER EXTINGUISHER WAS EMPTY.

TEST OF EXTINGUISHERS ON GASOLINE FIRES.

*To illustrate paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*

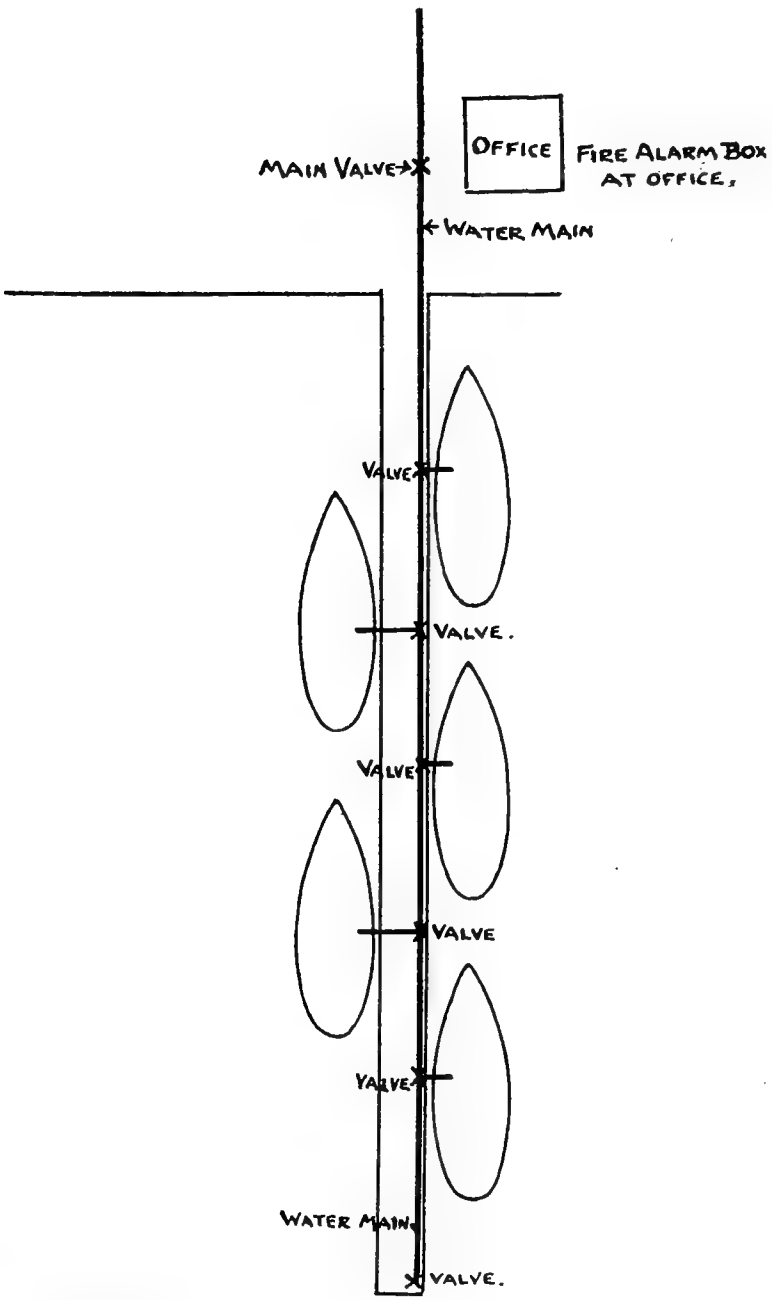
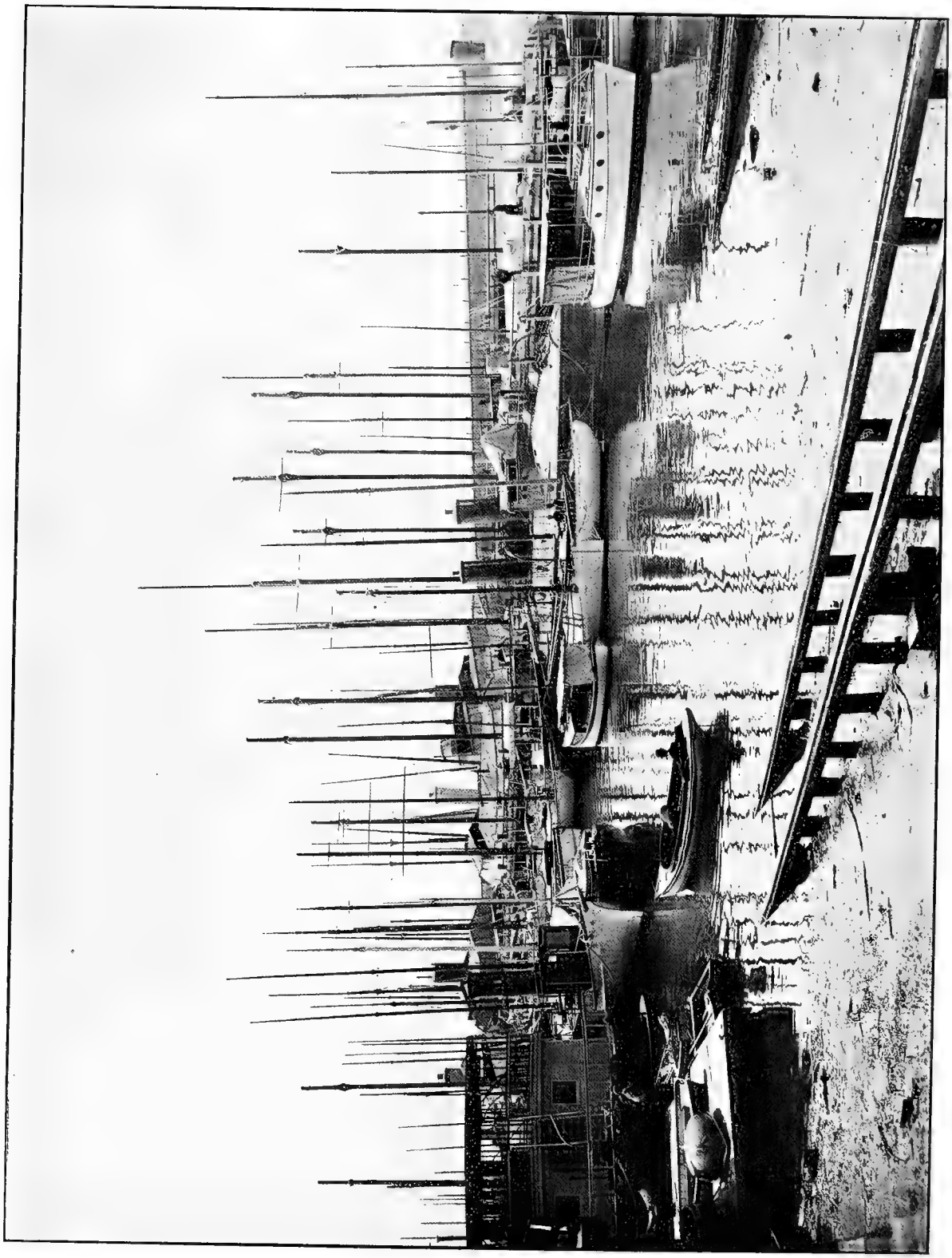


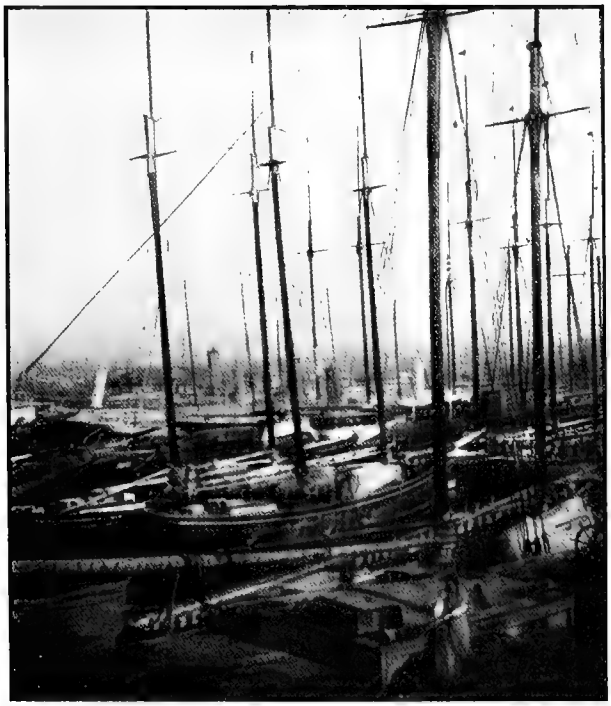

DIAGRAM OF A LAY-UP ARRANGEMENT WHERE WATER CAN BE HAD ALMOST INSTANTLY ON ANY OF THE BOATS, AND THE CITY FIRE DEPARTMENT PROMPTLY SUMMONED.

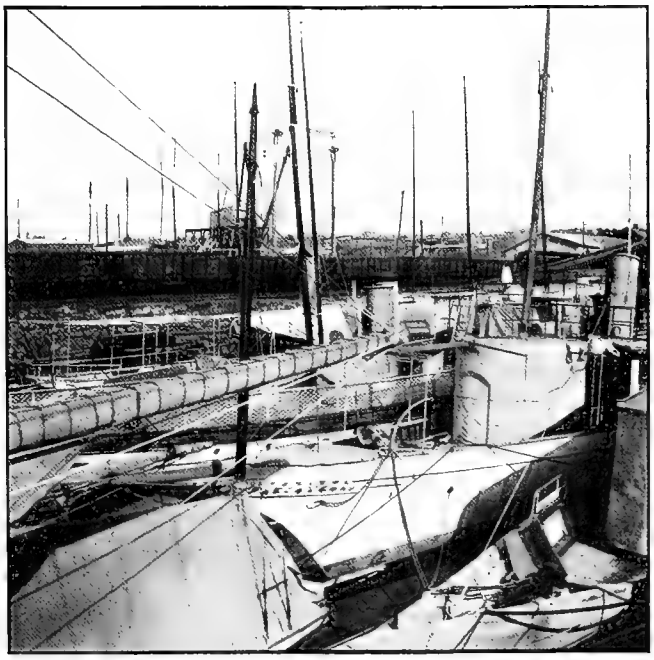
*To illustrate paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*



A Typical Yacht Basin in Winter.

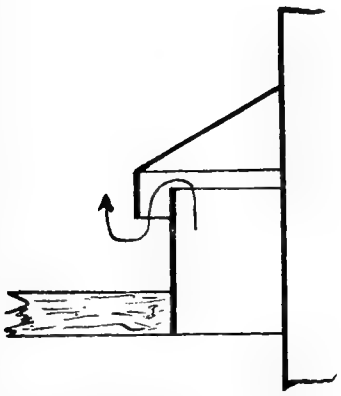
*To illustrate paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*



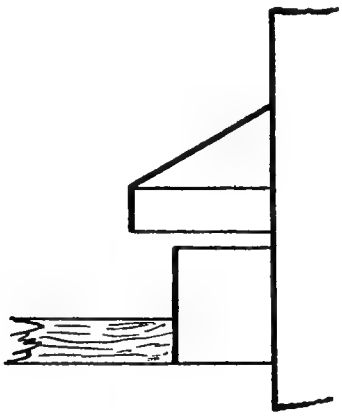


SHOWING SOME BAD LAY-UP CONDITIONS—IMPOSSIBLE TO GET THE BOATS OUT AND INACCESSIBLE FOR FIRE-ENGINES.

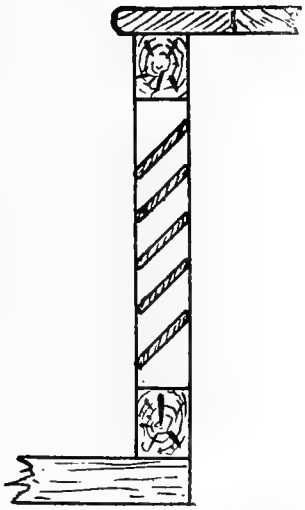
*To illustrate paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*



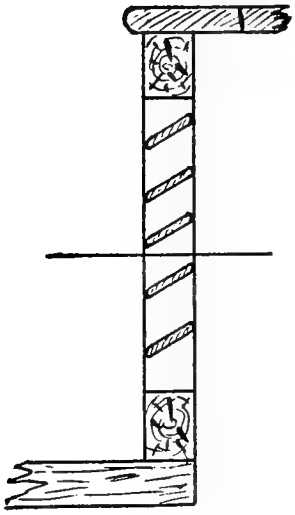
SKETCH A—SHOWING IMPROPER METHOD OF PROVIDING VENTILATION.



SKETCH B—SHOWING PROPER METHOD OF PROVIDING VENTILATION.



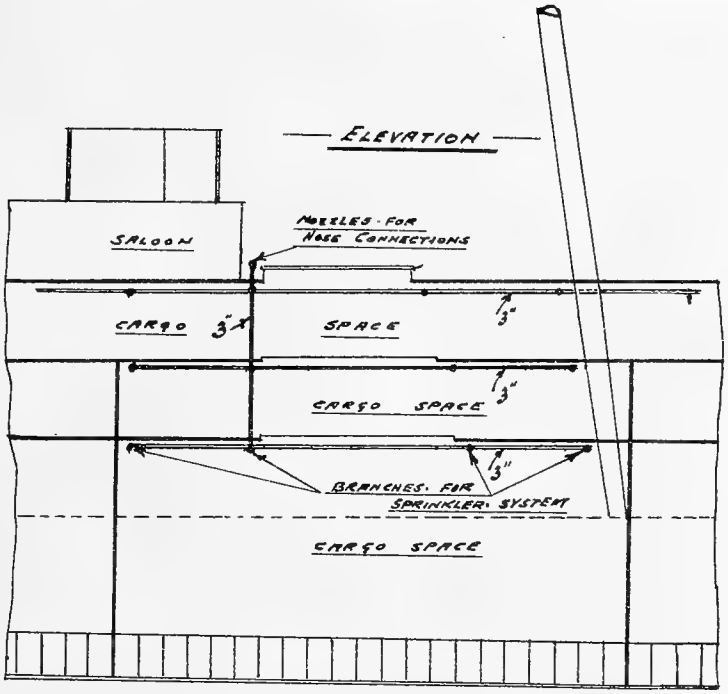
SKETCH C—SHOWING IMPROPER CONSTRUCTION.

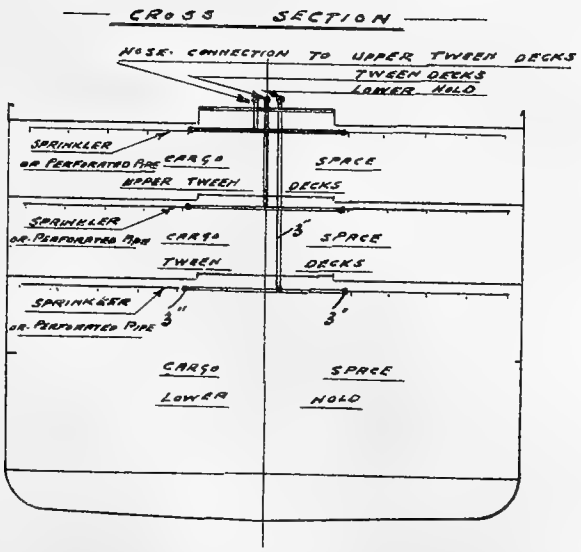


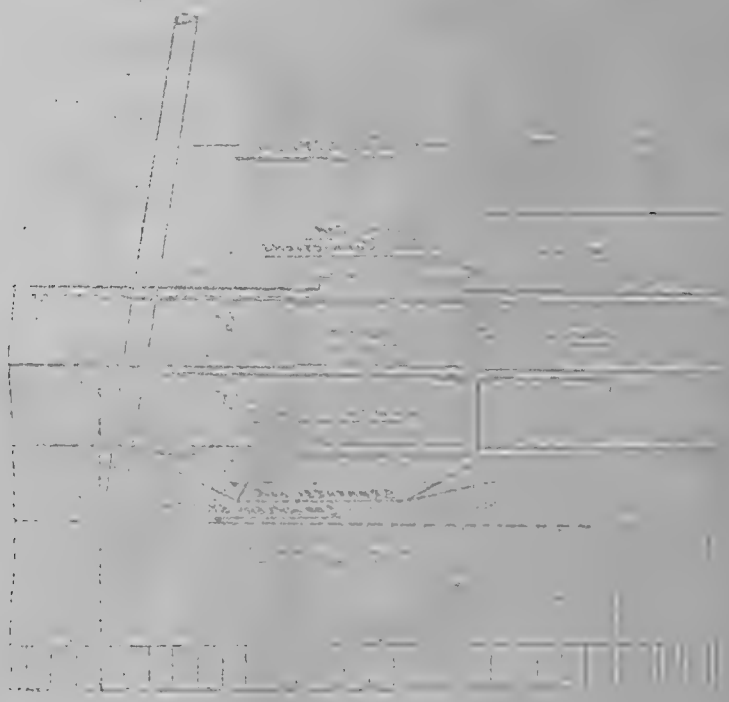
SKETCH D—SHOWING PROPER CONSTRUCTION.

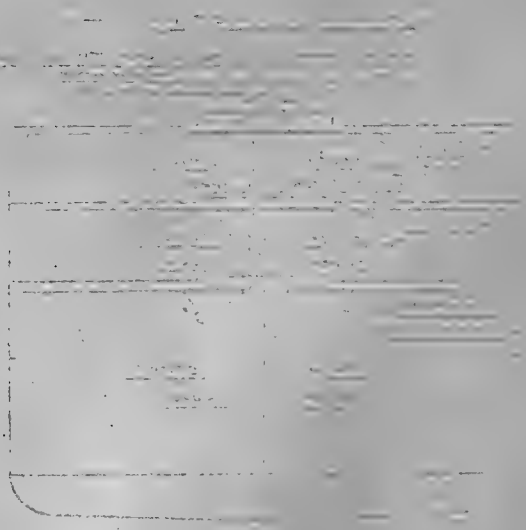
*To illustrate remarks by Deputy Chief John Kenlon, New York Fire Department, on paper on "Some Suggestions for Reducing the Loss by Fire on Vessels," by Samuel D. McComb, Esq., Member.*

## SUGGESTION FOR SPRINKLER OR PERFORATED PIPE SYSTEM TO HOLDS OF STEAMSHIPS







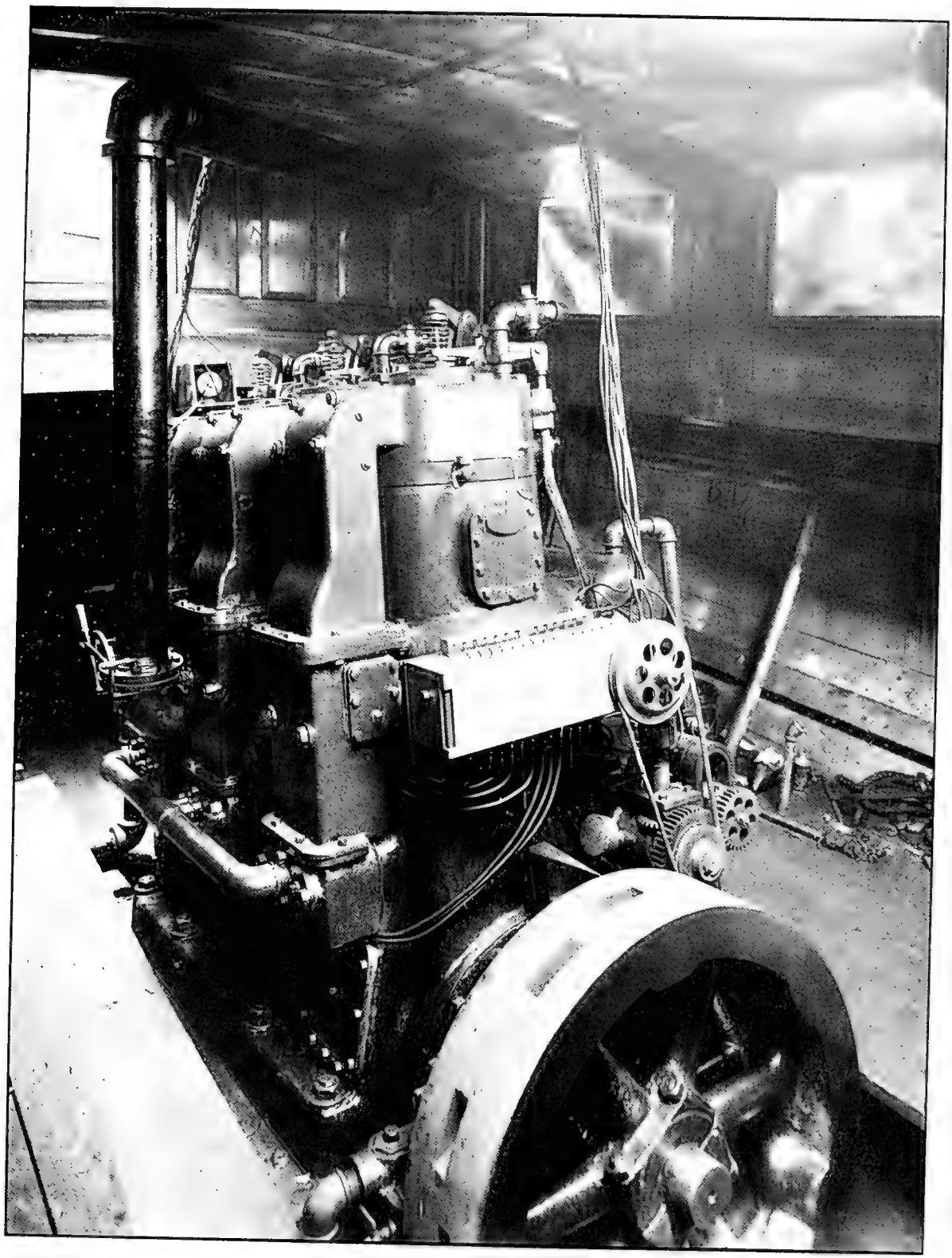
*To illustrate paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.*

PRODUCER GAS POWER BOAT, MARY A. SHARP.

*To illustrate paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.*

PRODUCER, MARY A. SHARP.

*To illustrate paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.*

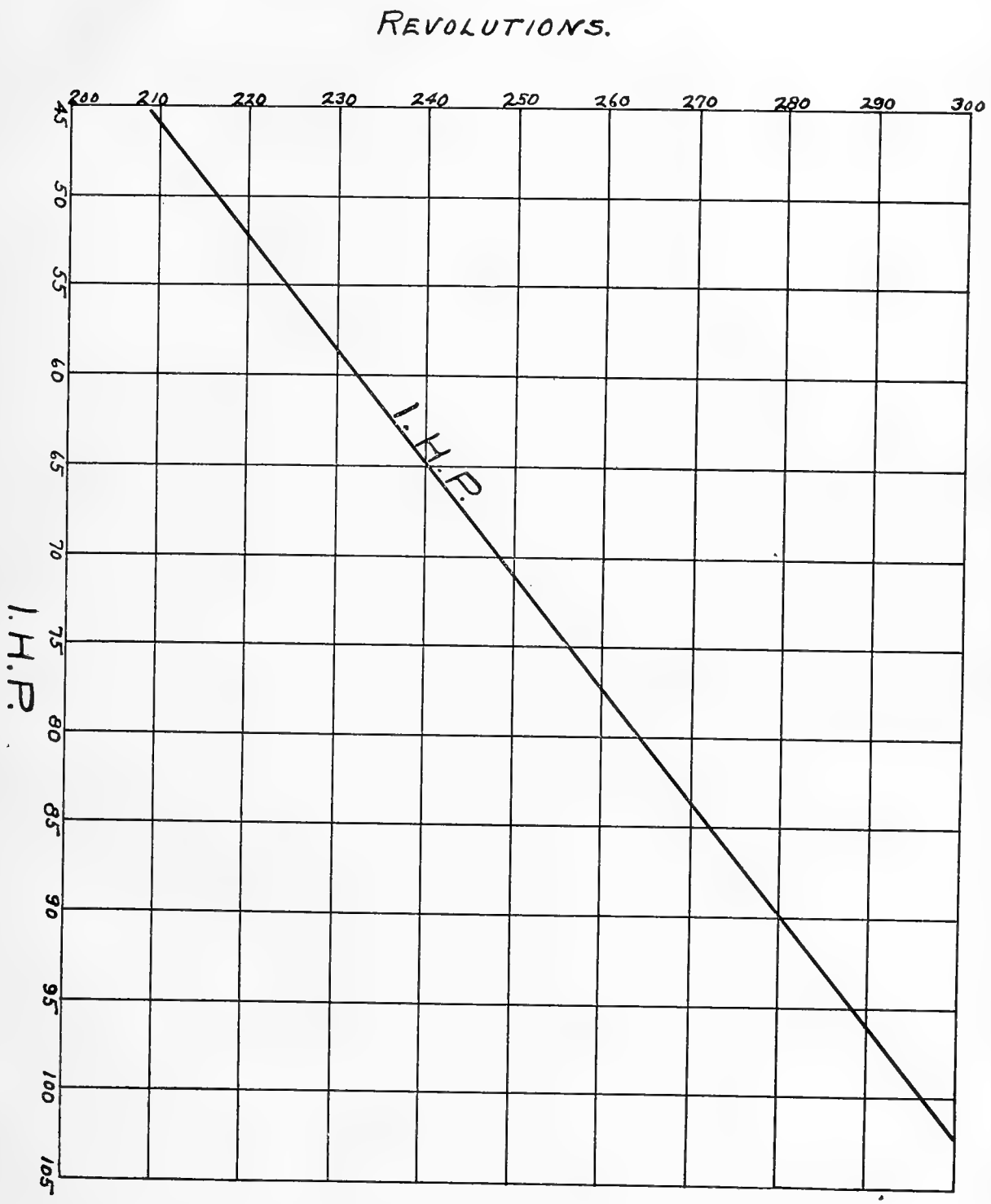


ENGINE, MARY A. SHARP.

*To illustrate paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.*

PRODUCER GAS POWER BOAT, SUPERIOR.

*To illustrate paper on "Two Marine Installations of Producer Gas," by Charles B. Page, Esq., Member.*



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